BETT TTEB

Effects of Thermal Upgrading on Electrical Wiring Systems in Houses

A RESEARCH REPORT

Effects of Thermal Upgrading on Electrical Wiring Systems in Houses

A RESEARCH REPORT

A State-of-the-Art Review of Problems
Induced in Residential Electrical Systems
by Energy Conservation Measures

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ABSTRACT/RESUME

This state-of-the-art review addresses concerns over possible adverse effects to the residential electrical wiring system caused by thermal upgrading measures in both new and existing construction. An annotated bibliography with a discussion of the more serious problems is presented and further studies are recommended.

* * *

Cet examen récent et poussé concerne l'incidence éventuelle sur le câblage électrique des résidences des mesures d'amélioration de l'isolation thermique dans les bâtiments, nouveaux et existants. Une bibliographie annotée, assortie d'une discussion des problèmes plus graves susceptibles de se poser, est jointe, et d'autres études sont recommandées.

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This particular report was prompted by concerns about electrical wiring systems in houses, particularly the hazards that might be induced in these systems by the indiscriminate application of energy conservation measures. A state-of-the-art review has been conducted, and the main part of the report is taken up by an annotated bibliography. The review identifies several potential hazards that might be induced, or worsened, by current energy conservation practices.

The state of the art may perhaps be summarized as follows: on the one hand there is a range of convincing scientific hypothesis, indicating that certain practices may induce electrical fire hazards, and on the other hand there is a large incidence of electrically-induced fires whose causes can rarely be identified with any certainty after the event. Thus, there is a gap between theory and practice, and there is an obvious need for a greater research effort in this area. Some of this research, relating to the intrinsic performance of old and new systems, might be seen as the responsibility of manufacturers and standards testing organizations. Other research, relating to processes of 'cause and effect' induced by thermal upgrading, should be considered the responsibility of the energy conservation sector.

This report is issued as part of the activities of the Buildings Energy Technology Transfer Program administered by the federal department of Energy, Mines and Resources. The objective of this program is to develop competent energy conservation technologies for buildings of all types, and to deliver these technologies to prospective users.

The report falls in the category of Low-Rise Residential buildings - a category that is managed by Saskatchewan Research council under contract to EMR.

The report does not necessarily reflect the views or policies of either Energy, Mines and Resources or Saskatchewan Research Council. However, the fact that it has been issued is an indication that each of these agencies is satisfied that it comes up to the standards of the BETT program and advances the state of the art.

D. Eyre
Saskatchewan Research Council

Cet examen technique poussé a été préparé en vue d'étudier les problèmes associés au câblage électrique et aux mesures d'amélioration de l'isolation thermique adoptées à des fins d'économie d'énergie dans le secteur résidentiel de faible hauteur. Une étude des documents techniques et un sondage auprès des chercheurs scientifiques et des entrepreneurs en isolation thermique aux États-Unis et au Canada ont été entrepris et les renseignements présentés sous forme de bibliographie annotée. Un examen de cette bibliographie a permis d'établir les constatations importantes suivantes:

1. Il y a pénurie de données techniques sur le rendement à long terme des canalisations électriques plus anciennes qui fonctionnent à des températures supérieures à 60°C, soit leur température nominale. Cette hausse de température peut être imputable à une surcharge des circuits, à l'augmentation de l'épaisseur de l'isolant au-dessus des canalisations, à la proximité des canalisations des sources de chaleur, à la température ambiante dans l'entretoit et supérieure à 30°C ou à une combinaison de ces facteurs.

2. Pour que les plafonniers intégrés puissent fonctionner de façon sûre dans les entretoits isolés, il faut prévoir un logement protecteur ouvert pour séparer les dispositifs des surfaces combustibles adjacentes; toutefois, cette méthode a pour effet d'accroître les pertes de chaleur et les risques de condensation à ces endroits.

3. Les matériaux d'isolation thermique installés dans les espaces dissimulés des murs et de l'entretoit peuvent entrer en contact avec les boîtes, les branchements et les boîtes de connexion. Les études sur place et en laboratoire n'ont pas permis d'obtenir des données suffisantes pour déterminer si une mauvaise installation pouvait compromettre la fiabilité ou la sûreté des dispositifs.

4. L'utilisation de composés à calfeutrer et de produits d'étanchéité en vue de minimiser les fuites d'air dans les prises de courant ou les

boîtes de branchement électriques devient pratique courante. Les données ne sont pas suffisantes pour déterminer l'incidence de ces matériaux qui pourraient entrer en contact avec les branchements électriques.

5. L'apparition de la condensation dans les boîtes électriques et la corrosion possible des branchements électrioques semblent dépendre de la situation géographique, de la quantité d'air évacuée et de l'endroit, et du genre de système de chauffage.

Par suite du nombre du limité de références mentionnées dans la présente étude, il appert que d'autre études sont requises pour mieux comprendre les domaines où des problèmes sont susceptibles de se poser. Les recommandations qui suivent découlent de la présente étude.

1. Les études en laboratoire doivent déterminer l'incidence de la température des conducteurs supérieure à 60°C sur la durée des matériaux isolants électriques dans le cas des canalisations plus anciennes (NMD-1, NMD-3, et notamment les gaines d'isolation en caoutchouc dont la quantité est conforme au code de l'électricité) et les câbles plus récents (soit les gaines d'isolation avec enveloppe de nylon et de polyéthyle réticulé).

2. Les études sur place doivent pouvoir déterminer la périodicité, l'endroit et la durée des températures qui se manifestent à plus de 60°C dans le cas des conducteurs de circuits de dérivation, et être axées notamment sur le câblage électrique qui contient de l'isolant en caoutchouc dont la qualité est conforme au code de l'électricité.

3. On devrait entreprendre des études en laboratoire et sur place en vue de confirmer les résultats préliminaires selon lesquels les substances isolantes qui pénètrent dans les prises d'électricité sont susceptibles de corroder de façon marquée les composantes électriques.

4. Des études de recherche doivent permettre de déterminer, l'incidence de l'augmentation des

températures sur le fonctionnement du câblage et des branchements électriques dans les boîtes de jonction placées dans le plafond.

5. Les études en laboratoire doivent permettre de déterminer, d'après les différentes conditions ambiantes, l'incidence à long terme des composés de calfeutrage et d'étanchéisation sur les branchements, les boîtes d'extrémité et les dispositifs électriques.

6. Il convient d'entreprendre des inspections sur place des bâtiments existants dont l'isolation thermique a été améliorée et des nouveaux bâtiments en vue de déterminer la périodicité et l'incidence de la condensation qui se manifeste dans le prises de courante et les panneaux de branchement.

7. D'autres modèles mathématiques de câblage et de dispositifs électriques entourés d'isolants thermiques doivent être élaborés en vue d'améliorer le rapport coût-efficacité des études en laboratoire et sur place qui sont de portée limitée.

1.0 INTRODUCTION

Throughout the U.S. and Canada, energy conservation programs advocate and financially support improvements in the thermal envelopes of both existing and new residential construction. Various preformed, loose fill and field-installed thermal insulations, air/vapour barriers, and sealant and caulking compounds are among the types of material being used to effect these improvements. It is the possible adverse interaction of these materials with the electrical wiring system, both from material property and installation standpoints, that has raised the concern of federal, provincial and municipal authorities.

The objective of this study is to examine any potential and/or actual problems associated with thermal upgrading measures in low-rise residential construction and the electrical wiring system. Using a North American perspective, a state-of-the-art review and annotated bibliography have been prepared to provide technical information on past and current research studies that address the objective. Published studies are the primary source of information for this study although internal reports and private communications are included to fill any gaps in the published data. In most cases the information is preliminary or exploratory because the sample size of laboratory and field data is too small for statistical validity.

For existing residential construction, info mation on the effect of thermal upgrading is included in the following areas: knob and tube wiring, non-metallic sheathed cable (including aluminum wiring), recessed and surface-mounted lighting fixtures, outlet and junction boxes, electrical switches and receptacles and electrical service entrance panels.

The study also addresses potential problems in new construction and includes a discussion of possible corrective measures.

1.1 Methodology

In undertaking this, the following methodology was used:

(1) Computer literature searches through seven data bases: National Newspaper Index, Safety Science Abstracts, Compendex, Inspec, Magazine Index, NTIS and Energynet (A description of the coverage and scope of each data base is given in Appendix A)

(2) Contacting of relevant technical experts primarily through telephone conversations to obtain further reference material or oral progress reports of on-going research studies (see Appendix B) for a list of organizations and personnel contacted; and

(3) Visits to outside organizations if telephone contacts indicated a need.

1.2 Organization and Use of Bibliography

The annotated bibliography is divided into four subsections: Sections 6.1 to 6.3 refer to existing residential construction and Section 6.4 includes references on new construction. Since the great majority of annotations are contained in subsections 6.1 and 6.2 (Electrical Wiring System and Thermal Upgrading Measures), these two sections were subdivided into specific topics. Since the sections created are not discrete divisions, a system of cross-referencing is used. Thus, a number of entries occur under several categories, but with complete citation, abstract and key word listing occurring under a pre-determined "primary" listing. When the same citation appears under "secondary" categories, reference is made to its primary listing for abstract, comments and key words.

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A number of items contained in this bibliography are drafts for limited circulation, private communications or internal reports. These items are included where the contained information is of sufficient importance to be of value to the reader. In such cases, further information on these topics can be obtained by contacting the author.

2.0 REVIEW OF BIBLIOGRAPHY

The operation of electrical systems results in the generation of heat. When the electrical wiring system is properly designed to withstand the imposed loads and environment, the generated heat should not affect either the reliability or the safety of the wiring system and any associated devices. However, changes in the load or environment caused by addition of thermal insulations or installation practices can adversely affect the system. For example, surrounding wiring with thermal insulation restricts heat dissipation from the wire and can lead to elevated conductor temperatures. The field installation of loose fill insulations in walls can result in the inadvertent filling of electrical outlet boxes with insulations which, in the presence of moisture, could possibly corrode or chemically attack wiring terminations. The following section reviews the current knowledge of potential and actual problems occurring between the electrical wiring system and thermal upgrading practices.For clarity, the review is divided into the same sections as in the bibliography. A discussion of potential problems occurring in thermally upgraded new construction completes this section. (Numbers in parentheses indicate annotated citations, in / / indicate references.)

2.1 Electrical Wiring System (Existing Construction)

2.1.1 Knob and Tube Wiring

The Canadian Electrical Code - Part I/11/ required that the electrical insulation of knob and tube wiring have a temperature rating of 60°C when it was first certified in 1938. This rating allows for a 30°C temperature rise over 30°C ambient; if the ambient exceeds 30°C, the code requires de-rating of the circuit. None of the reviewed studies indicate that the 60°C rating of the single conductors (knob and tube wiring) would be exceeded by a wire carrying full rated load (20 A) and surrounded by thermal insulation. However, one study/58/ conducted by Ohio State University on two Columbus, Ohio test houses measured attic space air temperatures up to 60°C. According to the code/11/, a 55°C ambient air temperature requires a 0.41 de-rating or an allowable ampacity of 8.2 for 60°C rated single conductors. Considering the magnitude of summertime air conditioning loads in a location such as southern Ontario, this requirement appears likely to be contravened. In 6.2.1.5, preliminary testing of wet thermal insulations over bare knob and tube conductors with 15 A loads did not indicate any significant corrosive or chemical attack after a 28-day exposure; however, the results obtained for one set of environmental conditions cannot be generalized to cover all conditions. It is apparent from the lack of technical information, that further laboratory and field studies are required to respond to potential problems especially regarding long-term insulation integrity.

2.1.2 Non-Metallic Sheathed Cable (NM)

Because of mutual self-heating effects in non-metallic sheathed cables (not more than three conductors as compared to the single knob and tube conductors), the Canadian Electrical Code reduced the maximum allowable current from 20 to 15 A for comparably sized wires (14 AWG copper and 12 AWG aluminum). A preliminary assessment of the differences in NM and knob and tube wiring could suggest that because of the juxtaposition of conductors in a NM-type cable, the possible embrittlement caused by thermal aging could produce more electrical problems (ie, short circuits) than for the separated

conductors in a knob and tube wiring system. Laboratory and field studies (6.1.2.1, 6.2.1.5, 6.2.5.5) have shown that at rated loads (15 A) these cables when surrounded by thermal insulation can exceed their rating, at least for 60°C rated cables (NMD-1 and NMD-3). However, the effect of these elevated temperatures on the long-term integrity of the electrical insulation is unknown. In addition, the frequency and duration of these temperature excursions in actual homes is not documented. Results of one U.S. field study (6.2.5.5) indicated that approximately 5% of monitored circuits exceeded their 60°C ratings, but no data on frequency or duration could be presented. In Canada, 60°C rated NMD cable contains either polyvinyl chloride (PVC) or "code grade rubber" electrical insulation. Based on information in 1976 Canadian Census on Dwelling and Households/58/, 60°C insulation of these types could exist in 2.5×10^6 single detached dwellings. More field data on the branch circuit temperatures in these homes is required to answer any questions regarding the long-term integrity of the electrical insulations. Appendix C lists the common types and constructions of residential electrical wiring together with approximate CSA certification dates.

Considering electrical code requirements/11/, allowable ampacities of 15 A are permitted for NM type cables (14 AWG conductors) based on a 30°C ambient temperature. With a 55°C ambient temperature, the cables would be de-rated to 6.1 A and result in an even greater possibility of code contravention as compared to knob and tube conductors.

Few studies considered the effects of thermal insulation over aluminum wiring and aluminum-wired connections. In one study (6.2.1.5), bare aluminum conductors were not significantly affected by the leachants from wet thermal insulations. However, a study of the predicted failure of aluminum-wired connections suggests that an increase in connection operating temperature could decrease median aluminum wire connection life by 2 to 10 times (6.1.2.2). This finding suggests that addition of thermal insulation to walls and ceilings of aluminum-wired houses could adversely affect connection life.

2.1.3 Recessed and Surface Mounted Lighting Fixtures

The Canadian Electrical Code - Part I (1982 edition) (6.1.2.7) permits the installation of recessed light

fixtures in insulated attics provided the temperature adjacent to conbustible surfaces is less than 90°C. Several studies describe the fire hazard involved when recessed fixtures are surrounded with thermal insulation (6.1.3.2, 6.1.3.4, 6.1.3.6) and indicate that this temperature limit can be met with properly designed protective enclosures (6.1.3.3, 6.1.3.4, 6.1.3.6). In Canada, provincial authorities do not appear to have agreed upon a recommended method for the installation of recessed light fixtures, with some prohibiting its use altogether and others requiring the construction of a suitably-sized protective enclosure around the fixture. Two studies (6.2.1.6, 6.2.4.3) suggest that recessed fixtures be removed altogether to alleviate the increased heat loss and risk of condensation that may occur with the use of open-topped protective enclosures. One U.S. study (6.1.3.4) indicates that the surface temperature of recessed fixtures surrounded with insulation could be reduced by taking advantage of the ceiling side thermal convection. Surface temperatures of a recessed fixture designed to this suggestion were found to be less than 175°C, a temperature that the authors of 6.1.3.7 consider safe for operation in contact with loose-fill or batt-type insulations (based on ignition temperatures). This conclusion could prove incorrect based on studies (6.3.1.4, 6.3.1.5) which indicate limiting safe temperatures of 100°C for combustible materials (wood joists) and 150°C for cellulosics under prolonged low level heating (~1 year).

Potential hazards associated with the use of thermal insulation over surface-mounted incandescent light fixtures (both flush and semi-flush types) are discussed in one study (6.1.3.5). Results from laboratory testing indicated that the surface temperature of some wiring associated with these fixtures was above the U.S. limit of 60°C even without thermal insulation. With insulation, the temperature limit was exceeded by as much as 30°C. Overlamping, mentioned as a potential hazard in other studies, was a further cause of significant temperature rises. Based on the test results in 6.1.3.5, a National Bureau of Standards study on installation techniques (6.2.4.2) recommended the installation of protective enclosures around the junction boxes of surface mounted fixtures.

2.1.4 Electrical Receptacles and Outlet Boxes

During the installation of loose-fill thermal insulations, the materials can penetrate electrical outlet and junction boxes (6.1.4.1, 6.2.1.5). The effect of insulation inside electrical boxes is uncertain although one exploratory National Bureau of Standards study (6.1.4.1) indicates significant corrosion of metallic components (receptacles) inside outlet boxes exposed to high relative humidities for periods up to 12 months with a resulting increase in shock hazard and energy loss. This study assumes that condensation in the walls (and outlet boxes) could be a potential problem because of the amount of air leakage through electrical penetrations. The occurrence of problems also depends on heating system type and location of electrical penetrations. In most older gas- and oil-heated houses the action of the furnace flue tends to induce air infiltration, thereby reducing the incidence of condensation. However, in flueless electrically-heated houses, inadequate air sealing could induce air exfiltration through electrical penetrations in the ceiling (ie, light fixtures) and increase the incidence of condensation. A second laboratory study (6.2.1.4) involving insulation inside outlet boxes indicates some superficial corrosion of metallic components but no adverse effect on the performance of the devices. Field studies containing observations of electrical components in insulated walls (6.2.5.2, 6.2.5.3) did indicate some cases of corroded wiring and outlet boxes but no evidence that these observations would compromise the safety or reliability of the devices.

2.1.5 Service Entrance Panels and Overcurrent Protection

The extent of "overfusing" in residential service entrance panels is well-documented (6.1.2.3, 6.2.1.4, 6.2.4.2, 6.3.1.1, 6.2.5.4, 6.2.5.5, 6.4.3). This abuse remains a major cause of electrical insulation deterioration with subsequent melting and ignition of insulation and adjacent combustible surfaces. In the U.S., service entrance panels in new construction use S-type fuse protection which is not interchangeable (as compard to Edison-base fuses).

For existing construction, one U.S. study (6.2.4.2) recommends the replacement of conventional Edison-base fuses with S-type fuse adaptors to eliminate possible overfusing.

Concerning thermal upgrading measures and residential construction, a specific method for insulating around service entrance panels on the inside of basement walls is suggested in one study (6.2.4.3). This technique involves framing and insulating the panel leaving it on the cold side of "an insulated and hinged panel". This suggested practice could have adverse effects on the overcurrent protection. By lowering the ambient temperature of the service entrance panel and associated fuse or circuit breaker protection, the devices may not operate at currents up to 140% of their rating (6.1.1.1). Combined with the frequency of incorrect overcurrent protection as reported in field surveys (6.3.1.1, 6.2.5.4) this suggested installation practice may result in unacceptably high wiring temperatures in insulated attics and walls.

2.1.6 Mathematical Modelling

One recommended method to assess the thermal effects of insulation surrounding wiring system components is computer modelling. Compared to field and laboratory assessments, it can be a relatively inexpensive source of information, and can indicate the occurrence of excessive temperatures of these components under different loads, building geometries and environmental conditions. Studies (6.1.3.4, 6.1.7.2, 6.2.1.5) involving predictive models generally show good agreement with experimental results and are considered an important adjunct to field and laboratory tests.

2.2 Thermal Upgrading Measures (Existing Construction)

2.2.1 Thermal Insulations

Some exploratory laboratory testing has been performed to determine the effects of specific thermal insulations on electrical wiring and associated

devices (6.1.1.1, 6.2.1.1, 6.2.1.5, 6.2.1.7). Various cellulose fibre, mineral fibre and urea-formaldehyde foam insulations were evaluated in contact with electrical wiring components. Test results in the majority of studies indicated that corrosion or chemical attack of wiring system components is not sufficient to cause a significant decrease in their safety or reliability; however, the same studies agree that the heat build-up that affects all electrical wiring and components when surrounded by insulations could be a potential problem.

2.2.2 Sealants and Caulking Compounds

One study by Blaga (6.2.2.1) details the effects of commercially available sealants on various types of electrical wiring. Results from laboratory tests, in which cable materials were encapsulated with sealants, were obtained at one set of conditions (25°C and 50% relative humidity) and should not be generalized to cover all possible conditions. For example, some field observations of air-sealing in residential construction indicate the use of sealants to fill the spaces between receptacle body and outlet box and the electrical penetrations for wiring directly behind electric baseboard heaters. The effect of these materials inadvertently placed in contact with electrical terminations requires more study.

2.2.3 Gasketing and Weatherstripping Materials

The installation of flexible foam gaskets behind receptacle faceplates is becoming an accepted practice to reduce air leakage at electrical outlets. At present, certification of these materials is conducted in accordance with Canadian Standards Association Electrical Bulletin No. 1373 (June 15, 1982) and includes requirements for electrical safety (dielectric withstand, insulation resistance and flame tests) but not for air leakage. Concerning flame testing, one study (6.1.5.1) suggested that the use of a non-flaming ignition source would represent more accurately the cause of an electrical fire (ie, electrical arc, overheating connection) and could result in the use of different gasketing materials.

2.2.4 Installation of Thermal Upgrading Measures

The three studies that concerned the installation of thermal insulation around electrical wiring and devices suggest prior inspection of all electrical fixtures and suspect wiring (6.2.4.1, 6.2.4.2, 6.2.4.3). One of the U.S. studies (6.2.4.2) suggests inspection of outlet and junction boxes after reinsulation to remove any materials that may have entered the boxes. The appropriate branch circuit should be de-energized prior to this operation. No such mention was found in the Canadian document (6.2.4.3). The U.S. study suggests the installation of protective barriers around both recessed fixtures and the junction boxes associated with surface mounted fixtures. The Canadian document suggests the removal of recessed light fixtures altogether since the installation of properly sized protective enclosures would increase heat loss and the risk of condensation. No mention is made of junction boxes for surface-mounted light fixtures.

2.2.5 Field Studies

Observations from the field studies covered in this review appear to indicate that the occurrence of condensation in concealed wall and ceiling spaces with possible corrosive attack of electrical wiring components depends on geographic location and the extent and location of air sealing. In the U.S. several limited field studies (6.2.5.1, 6.2.5.2, 6.2.5.3) conducted inspections of wall cavities after insulation retrofitting and revealed no significant moisture damage or corrosion of electrical components. By comparison one Canadian study (6.2.5.6) showed examples of significant condensation problems in attic spaces resulting from a combination of geographic location and high indoor relative humidity (achieved because of well-insulated walls and ceilings and triple-glazing and the ductless heating system).

Another field study (6.2.5.4) details the results of electrical inspections in 157 homes conducted to determine the type and number of electrical wiring system deficiencies. Seventy-eight percent of the homes had system deficiencies including overfusing,

lighting system problems and fuse/circuit breaker problems. Concerning field data on temperatures of electrical wiring encapsulated in thermal insulation, one study (6.4.5) observed that approximately 38% of the monitored circuits exceeded 60°C (the Canadian temperature limit for NMD-1 and NMD-3), although the frequency and duration of these temperatures was not given. In addition, of the 164 residences that returned information on overcurrent protection, 64 had at least one circuit with an oversized circuit breaker or fuse.

2.3 Electrical Fires Involving Thermal Insulation

In order to gain a perspective on actual hazards a review of statistics on electrical fires involving thermal insulations is included. Based on U.S. Fire Administration records one Consumer Product Safety Commission study (6.3.1.1) states that 75,000 fires per year or 10% of the total fires are associated with residential electrical wiring systems. Fixed wiring, recessed lighting fixtures and thermal insulations are identified as the materials first ignited in the majority of cases. A second Consumer Product Safety Commission study (6.3.1.2) is more comprehensive in its analysis of fire records but not statistically valid concerning fire causes primarily because the fire investigation reports came from local fire personnel in diverse jurisdictions. The study concludes that the most common problem leading to fires involving thermal insulation was the improper installation of the materials. Inspection of electrical wiring is suggested before installation of thermal insulation with periodic checks thereafter.

The Canadian and Ontario fire records (6.3.1.6, 6.3.1.7) estimate that 17% of the total fires are electrical in origin. Compared to the 10% mentioned in U.S. Fire Records, this could suggest a more hazardous situation in Canada with respect to electrical fires, although methods in fire reporting could account for the difference.

2.4 New Construction

With the exception of knob and tube wiring and 60°C rated electrical cable (NMD-1 and NMD-3), the potential problems reviewed in the preceding section on existing construction can occur in new construction with some minor differences. Compared to 60°C rated cable, there is no information to indicate that 90°C cable will exceed its temperature rating with correctly matched overcurrent protection. In this respect, there has been some suggestion, although not documented, that a comparison of the properties of 60°C and 90°C rated cables after long-term thermal aging would not yield any significant differences.

One study (6.4.3) suggests a lack of compatibility of the present electrical wiring system with new house construction methods. Reference is made to inappropriate wire size for increased levels of thermal insulation, the inadequacy of present overcurrent protection devices for preventing fires, and the need for more effective sealing methods for outlet and switch boxes. With respect to the latter suggestion, the new "double" wall concept mentioned in 6.4.1 appears to effectively meet this need.

Economic pressures are forcing the marketplace to evolve substitutes for older electrical system components (ie, nylon-sheathed cable, cross-linked polyethylene insulated cable, PVC outlet and junction boxes). Studies on the performance of these relatively new components in thermally-improved new house construction were not located. The simple increase in levels of thermal insulation in these homes without corresponding improvements to the air/vapour barrier could lead to increased risk of condensation in concealed wall and ceiling spaces. Indeed, even with improvements in both insulation and air leakage, some installation or building design oversights, such as thermal bridging at corners or inadequately sealed electrical penetrations, could focus air leakage and potential condensation and electrical safety problems at those locations.

3.0 CONCLUSIONS

1. Laboratory studies have shown that the temperature rating of 60°C NMD-1 and NMD-3 cables is exceeded when the cables operated at maximum load are surrounded by thermal insulation levels of R_{SI}-3.5; the effect of long term exposure of the cables to these temperatures is not well understood.

2. "Code grade rubber" insulation used in knob and wiring, NMD-1 and NMD-3 cables had a 50°C rating in the U.S. until 1938 and 60°C rating in Canada from 1938 to 1966. There is a lack of data concerning the effect of surrounding thermal insulations on the physical and electrical properties of these electrical insulations.

3. Properly-installed open-topped barriers can maintain recessed fixture surface temperatures below the present Canadian Electrical Code requirement of 90°C; however, the installation of these enclosures increases heat loss and the risk of condensation at these locations.

4. A U.S. study indicates that wiring temperatures associated with the ceiling junction boxes of surface-mounted light fixtures can exceed 60°C in insulated attics.

5. Thermal insulations can penetrate junction and outlet boxes during the re-insulation of walls and ceilings. Significant corrosion of electrical components inside electrical boxes was observed in one U.S. laboratory study. Observations from U.S. field studies and Canadian laboratory tests do not confirm these findings. However, adding insulation inside the walls and ceilings of existing and new construction without careful attention to the air/vapour barrier especially at electrical penetrations could focus moisture problems at these locations.

6. The framing and insulation of service entrance panels can result in a lower ambient temperature during the heating season. This reduced temperature can affect the operation of overcurrent protection and allow higher than rated loads in branch circuits.

7. Mathematical modelling of electrical system components surrounded by thermal insulations shows good agreement with laboratory and field measurements.

8. There is a lack of data on the effect of caulking compounds and sealants on electrical system components. One study conducted at one set of ambient conditions observed no adverse effect of these materials on electrical jacketing, insulation or conductors.

9. Electrical inspections in existing U.S. homes indicate that approximately one-third of the inspected homes contain at least one oversized fuse or circuit breaker.

10. There is a lack of data on the effects of thermal upgrading measures on new electrical system components (ie, PVC outlet boxes, nylon sheathed wiring) used in both existing and new construction.

11. New construction designs incorporating the "double" wall concept avoid problems with electrical penetrations by installing wiring and outlets between the air/vapour barrier and the interior finish.

4.0 RECOMMENDATIONS

From the limited number of citations presented in this review, it is apparent that further studies are required for a better understanding of potential problem areas. Following are some recommendations arising from this study.

1. Laboratory studies should determine the effects of conductor temperatures greater than 60°C on the long term integrity of electrical insulations in older cables (NMD-1, NMD-3 including "code grade rubber" insulations) and newer cables (nylon-sheathed and crosslinked polyethylene insulation).

2. Field studies should determine the frequency, location and duration of branch circuit conductor temperatures >60°C with special attention to wiring which contains "code grade rubber" insulation.

3. Laboratory and field studies should be conducted to confirm preliminary findings that insulation penetration into electrical outlets can cause significant corrosion to electrical components.

4. Research studies should determine the effect of increased operating temperatures due to higher levels of insulation on the performance of wiring and wiring connections in ceiling junction boxes.

5. Laboratory studies should determine, under various ambient conditions, the long term effects of caulking and sealant compounds on electrical wiring connections, terminations and devices.

6. Field inspections should be made of thermally-upgraded existing and new construction to determine the frequency and effect of condensation in electrical outlets and service entrance panels.

7. Additional development of mathematical models of wiring and devices surrounded by thermal insulation should proceed to improve the cost-effectiveness of limited laboratory and field investigations.

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6.0 ANNOTATED BIBLIOGRAPHY

6.1. Electrical Wiring System

6.1.1 Knob and Tube Wiring

Reference No	6.1.1.1
Title	Effects of Thermal Insulation on Knob and Tube Wiring
Author(s)	S.J. Oda
Publisher/Date/Pages	Ontario Hydro Research Division/March 1978
Available from/Price	Ontario Hydro Research Division 800 Kipling Avenue Toronto, Ontario M8Z 5S4
Catalogue & Indexing Numbers	Ontario Hydro Research Report No. 78-96-K
Key Words	Knob and tube wiring/glass fibre/cellulose fibre/urea-formaldehyde foam/electrical insulation resistance/dielectric strength
Sector Applicability	Office Residential Restaurants Industrial Retail

Abstract

This report describes preliminary laboratory testing of glass-fibre, cellulose fibre and urea-formaldehyde foam insulation over knob and tube wiring. Conductor temperatures were measured as a function of insulation thickness (up to Rsi 7.7) and electrical load (9 A, 12 A, and 15 A) under ambient conditions of 23°C and 50 per cent relative humidity. Insulation and energized wiring installed in simulated wall stud spaces, were exposed for 96 h at 50°C and 95% RH. Insulation resistance and dielectric strength measurements indicated no apparent effect on electrical insulation after the exposure.

Reference No.	6.1.1.2
Title	Effects of Installation of Thermal Insulating Materials on Knob and Tube Wiring in Old Residential Structures
Author(s)	R.L. Pescatore
Publisher/Date/Pages	Progress Report by Underwriters Lab Inc. (Santa Clara, CA) to Pacific Gas and Electric (San Francisco, CA)/March 1978
Available from/Price	N/A
Catalogue & Indexing Numbers	N/A
Key Words	Knob and tube wiring/thermal insulation/residences/ branch circuit wiring/field survey/chemical and corrosive effects
Sector Applicability	Office Residential Restaurants Industrial Retail

Abstract

This PG&E sponsored study conducted by Underwriters Lab Incorporated investigated the effects of retro-fit thermal insulation (glass, mineral and cellulose fibre loose fills and urea-formaldehyde foam) on the temperature of energized knob and tube wiring in the walls of actual homes. A total of seven wall sections were retrofitted with these insulations and the conductor temperatures recorded as a function of current and insulation type. Visual observations were made to check for possible chemical effects of the urea-formaldehyde foam on wire, terminations, insulation and junction boxes.

Comments	Since this was a progress report for information only, no conclusions or recommendations are made by Underwriters Lab Incorporated regarding the acceptability of installing insulations over knob and tube wiring. Their report did indicate after exposure to 40.5 and 60 A that "no visually noticeable damage to the electrical insulation (ie, hardening of the rubber) or charring or melting of the thermal insulation" was observed. The smell of rubber was noticed during the 60 A tests.

Reference No.	6.1.1.3
Title	Performance of Loose Fill Cellulose Fibre and Polystyrene Foam Insulations over Knob and Tube Wiring
Author(s)	S.J. Oda
Publisher/Date/Pages	Ontario Hydro Research/September 1978
Available from/Price	Ontario Hydro Research Division 800 Kipling Ave Toronto, Ontario M8Z 5S4
Catalogue & Indexing Numbers	Ontario Hydro Research Report No. 78-378-K
Key Words	Loose fill polystyrene foam/loose fill cellulose fibre/ knob and tube wiring/insulation resistance/dielectric strength
Sector Applicability	Office Residential Restaurants Industrial Retail

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Abstract

This exploratory study assesses:

(a) the effect of the thermal insulation surrounding energized knob and tube wiring under cyclic ambient conditions (3 days @ 50°C and 95% relative humidity followed by 4 days @ 23°C and 50% relative humidity for a total exposure of 4 weeks).

(b) the potential fire hazard of cellulose fibre and shredded polystyrene foam installed over bare knob and tube wiring loaded up to 30 A.

No deterioration of the knob and tube wiring insulation was observed after comparing the insulation resistance and dielectric strength measurements of exposed samples and controls. Knob and tube wiring temperatures of 152°C were measured with loads of 30 A and thermal insulation levels of RSI 7.0.

Comments

The limited number of laboratory tests conducted in this study does not permit generalized statements to be made regarding any potential fire hazard of loose fill insulations over bare knob and tube wiring.

Reference No.	6.1.1.4
Title	Effects of Thermal Insulation on the Reliability and Safety of Residential Electrical Wiring
Author(s)	S.J. Oda
Publisher/Date/Pages	Ontario Hydro Research Division/March 1981
Available from/Price	Ontario Hydro 800 Kipling Ave Toronto, Ontario M8Z 5S4
	Refer 6.2.1.5

6.1.2 Non-Metallic Sheathed Cable

Reference No.	6.1.2.1
Title	Exploratory Study of Temperatures Produced by Self-Heating of Residential Branch Circuit Wiring When Surrounded by Thermal Insulation
Author(s)	R.W. Beausoliel, W.J. Meese and L.S. Galowin
Publisher/Date/Pages	U.S. National Bureau of Standards/July 1978.
Available from/Price	National Technical Information Service Springfield, VA 22161
Catalogue & Indexing Numbers	NBSIR78-1477
Key Words	Branch circuit wiring/electrical fires/heat generation in receptacles/insulated buildings/overheating conductors/residential branch circuit wiring/thermal insulation and electrical wiring
Sector Applicability	Office Residential Restaurants Industrial Retail

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Abstract

Preliminary determinations under laboratory conditions were made of temperatures that might develop on residential electrical wiring covered by thermal insulation when carrying rated currents or currents slightly above rated values.

Comments

A temperature of 148°C was measured on closely paralleled non-metallic sheathed cables carrying 27 A (135% rating) for 1 h and surrounded by 2 layers of R-11 fibreglass insulation (115°C at 20 A and 2-1/2 h). The maximum allowable operating temperature for these cables is 60°C.

A temperature of 98°C was measured on a single length of NMD cable carrying 27 A (125% rating) for 1 h when surrounded by 2 layers of R-11 glass fibre (67°C at 20 A and 1-1/2 h).

Temperatures were not high enough to ignite the thermal building materials.

Urea-formaldehyde foam and cellulose fibre insulations can penetrate and fill outlet boxes and contact screws of duplex receptacles contained in the boxes.

Reference No.	6.1.2.2
Title	Insulated-Splicing Connections - Predicted Failure Rate
Author(s)	J.T. Strack
Publisher/Date/Pages	Ontario Hydro Research Division/October 1981
Available from/Price	Ontario Hydro - Research 800 Kipling Avenue Toronto, Ontario M8Z 5S4
Catalogue & Indexing Numbers	Ontario Hydro Research Report No. 81-290-K
Key Words	Predicted connection life/aluminum wiring
Sector Applicability	Office Residential Restaurants Industrial Retail

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Abstract	This study states that an increase in connection operating temperature of 10°C may decrease the median aluminum wire connection life by 2 to 10 times.
Comments	This finding could have an effect on connection reliability when the walls and ceilings of existing aluminum-wired homes are thermally upgraded.

Reference No.	6.1.2.3
Title	Insulation May Cause Wiring Code Violations
Author(s)	Electrical World
Publisher/Date/Pages	Electrical World/November, 1981
Available from/Price	Electrical World
Catalogue & Indexing Numbers	N/A
Key Words	Branch circuit wiring/light fixtures/thermal insulation
Sector Applicability	Office Residential Restaurants Industrial Retail

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Abstract — "Some 38% of residential branch circuits are operating at or above the temperature limit they were designed for under the (US) National Electrical Code. The extent of the hazard isn't known; however, because the duration of temperature excursions is unknown". About 70% of these temperature excursions are near light fixtures.

Comments — This article is essentially a synopsis of Faison's work in 6.4.5.

Reference No.	6.1.2.4
Title	Effects of Thermal Insulations on Electrical Connections and Outlet Boxes
Author(s)	Robert W. Beausoliel, James R. Clifton, William J. Meese
Publisher/Date/Pages	U.S. National Bureau of Standards/April 1981/52 pgs
Available from/Price	National Technical Information Service Springfield, VA. 22161 $8.00

Refer to 6.1.4.1

Reference No.	6.1.2.5
Title	Modeling for Determination of Temperatures of Electrical Cables Within Thermally Insulated Walls (Interim Report)
Author(s)	David D. Evans
Publisher/Date/Pages	U.S. National Bureau of Standards/October 1980
Available from/Price	National Technical Information Service Springfield, VA 22161
	Refer to 6.1.7.1

Reference No.	6.1.2.6
Title	Calculated Operating Temperatures of Thermally-Insulated Electric Cables
Author(s)	David D. Evans
Publisher/Date/Pages	U.S. National Bureau of Standards/January 1981
Available from/Price	National Technical Information Service Springfield, VA 22161

Refer to 6.1.7.2

Reference No.	6.1.2.7
Title	Canadian Electrical Code Part 1 (14th edition) "Safety Standard for Electrical Installations"
Author(s)	Canadian Standards Association
Publisher/Date/Pages	Canadian Standards Association/1982
Available from/Price	Canadian Standards Association 178 Rexdale Blvd., Rexdale, Ontario, Canada M9W 1R3
Catalogue and Indexing Numbers	CSA C22.1-1982

6.1.3 Lighting Fixtures

Reference No.	6.1.3.1
Title	Incandescent Lamp Approvals and Lighting Fixture Temperature Problems
Author(s)	J.O. Kentner
Publisher/Date/Pages	IAEI News/January 1969
Available from/Price	N/A
Catalogue & Indexing Numbers	N/A
Key Words	Thermal insultion/light fixtures/overheating
Sector Applicability	Office Residential Restaurants Industrial Retail

Abstract

This article summarizes the changes in the testing that were developed to minimize overheating in incandescent surface-mounted ceiling type and ceiling pan-type fixtures. Included in these changes were the upgrading of branch circuit wiring to 90°C from 60°C, the use of 15 cm of thermal insulation in the test ceiling, and a room ambient of 35°C.

Reference No.	6.1.3.2
Title	Cellulose Fibre Thermal Insulation Over a Recessed Pot Light
Author(s)	S.J. Oda
Publisher/Date/Pages	Ontario Hydro Research Division/May 1978
Available from/Price	Ontario Hydro Research 800 Kipling Avenue Toronto, Ontario M8Z 5S4
Catalogue & Indexing Numbers	Ontario Hydro Research Report No 78-214-K
Key Words	Cellulose fibre insulation/recessed light fixture/protective enclosure
Sector Applicability	Office Residential Restaurants Industrial Retail

Abstract

This preliminary study investigates the effect of cellulose fibre insulation installed over a recessed light fixture with and without a protective enclosure. The study describes the difficulty in constructing an enclosure that keeps fixture surface temperatures below 150°C and surrounding combustible surfaces below 90°C while preventing excessive heat loss and possible condensation problems. The report suggests that the installation of recessed pot light fixtures be avoided.

Reference No.	6.1.3.3
Title	Protective Enclosures for a Recessed Pot Light Fixture
Author(s)	S.J. Oda
Publisher/Date/Pages	Ontario Hydro Research/December 1978
Available from/Price	Ontario Hydro Research Division 800 Kipling Ave Toronto, Ontario M8Z 5S4
Catalogue & Indexing Numbers	Ontario Hydro Research Report No. 78-569-K
Key Words	Recessed light fixtures/protective enclosures/ insulated ceilings
Sector Applicability	Office Residential Restaurants Industrial Retail

Abstract

This report describes tests on two types of protective enclosure for recessed light fixtures in insulated ceilings. Of the two, the open-topped enclosure provided more effective protection against overheating of the pot light. Adjacent wood joist temperatures reached 90°C with a 100 W pot light in the chimney enclosure.

Reference No.	6.1.3.4
Title	Recessed Light Fixture Test Facility
Author(s)	D.W. Yarbrough, K.T. Yoo and P.B. Koneru
Publisher/Date/Pages	Oak Ridge National Laboratory/July 1979
Available from/Price	Oak Ridge National Laboratory Oak Ridge, Tenn.
Catalogue & Indexing Numbers	ORNL/SUB-7504/3
Key Words	Recessed light fixture/cellulose insulation/ electrical wiring
Sector Applicability	Office Residential Restaurants Industrial Retail

Abstract

This study describes tests on eleven recessed light fixtures installed in cellulose fibre insulated attic sections. Tests were conducted both with and without barriers to separate the cellulose insulation from the fixtures, at various fixture power levels, and thermal insulation levels. Included in the report is a three-dimensional mathematical model of two of the fixtures studied. Conclusions stated in the report include the following:

- Dangerous operating temperatures were observed when recessed fixtures were covered with loose fill cellulose insulation (misapplied). Fires resulted when cellulose covered fixtures were overpowered.

- Operating temperatures can be maintained at safe levels if insulated fixtures are mounted with a barrier that permits convective heat transfer from the attic side of the fixture. Temperatures, however, rise to unacceptable limits if the barrier is covered and the attic side of the fixture loses its contact with the surrounding air space.

- Temperatures above 90°C were routinely observed for ceiling joist sections adjacent to powered fixtures.

- Power cable temperatures were judged to be unacceptably high at the point of fixture entry for fixtures covered with cellulose insulation. The cable temperature drops rapidly with distance from the heated fixture.

Comments

An analysis of experimental data and the results of the mathematical model indicate that an increased heat transfer area on the ceiling side of recessed light fixtures could be used to limit maximum operating temperatures. This finding appears to have led to the development of the recessed fixture in 6.1.3.7.

Reference No.	6.1.3.5
Title	Temperature Measurement of Operating Surface-Mounted Lighting Fixtures
Author(s)	P. Michael Fulcomer
Publisher/Date/Pages	U.S. National Bureau of Standards/September 1979
Available from/Price	National Technical Information Service Springfield, VA 22161
Catalogue & Indexing Numbers	NBSIR79-1912
Key Words	Surface-mounted incandescent lighting fixture/ thermal insulation/overlamping/hazardous temperatures/branch circuit wiring/electrical junction box/load current/thermocouple
Sector Applicability	Office Residential Restaurants Industrial Retail

Abstract

Potentially hazardous temperatures may result from adding thermal insulation in the attic above surface-mounted incandescent fixtures and/or operating these fixtures with lamps of higher wattage than specified. This study was concerned with the range of temperatures generated (1) within the fixture, (2) within the electric junction box associated with the fixture and (3) on the adjoining attic and ceiling surfaces.

Test results indicate that the addition of minimal insulation (equivalent to RSI 1.9) over a surface mounted fixture which contains two or more rated lamps, is likely to cause normal household branch circuit supply wiring associated with the fixture to operate above its 60°C temperature rating. Overlamping (using lamps of higher wattage than specified for the fixture) and/or additional load current flowing through the branch circuit will cause even higher supply wire temperatures.

With all three conditions present (ie, insulation over the fixture, overlamping, and an additional 15 A load current flowing through the supply wire), the tests indicate that the temperature of associated branch circuit wiring will exceed 80°C for a one lamp fixture and 100°C for fixtures with two or more lamps.

Comments

Other observations in this report include:

(1) Most of the temperature increase due to thermal insulation is evident with a level of R_{SI}-1.9; going from R_{SI}-1.9 to R_{SI}-5.8 causes only a minor increase (-5°C) in temperatures in and around fixtures.

(2) The addition of a 15 A load to branch circuits results in a 15 to 20°C temperature rise on associated branch circuit wiring.

(3) The branch circuit wiring is likely to be the first component of surface-mounted lighting fixtures to exceed its rating. (Assuming a 60°C temperature rating).

Reference No.	6.1.3.6
Title	Temperature Measurement on Operating Recessed Light Fixtures
Author(s)	P. Michael Fulcomer
Publisher/Date/Pages	U.S. National Bureau of Standards/September 1979
Available from/Price	National Technical Information Service Springfield, VA 22161
Catalogue & Indexing Numbers	NBSIR79-1913
Key Words	Recessed incandescent lighting fixture/thermal insulation/hazardous temperatures/protective barrier/branch circuit wiring/electrical junction box/load current
Sector Applicability	Office Residential Restaurants Industrial Retail

Abstract

"Potentially hazardous temperatures may result from adding thermal insulation in the attic above recessed incandescent lighting fixtures. The National Electric Code for 1978 specifies that "...thermal insulation shall not be installed within three inches of a recessed fixture enclosure, wiring compartment or ballast and shall not be so installed above the fixture as to entrap heat and prevent the free circulation of air...". The purpose of this investigation was to determine the effectiveness of various protective barriers in maintaining the requisite three-inch spacing and in preventing over-temperature conditions when loose-fill insulation is installed around recessed lighting fixtures."

"For the devices tested, the results indicate that properly installed open-top barriers are sufficient to allow the fixture and associated branch circuit wiring to operate within specified ratings. However, a barrier closed at the top by any method, can cause branch circuit wiring, the external surface of the barrier and/or parts of the fixture to operate at temperatures above those designated as "safe"."

"The four critical (ie, a "safe") temperature locations and the limiting temperatures at each location are:

1. Outer surface of barrier device - 90°C maximum. Section 410-65(a) of the 78 NEC states that "fixtures shall be so constructed or installed that adjacent combustible material will not be subjected to temperatures in excess of 90°C."

2. Supply wire insulation - 60°C maximum. Household branch circuit wiring is normally of the type rated for 60°C. Since the temperature of the wire increases if there is an external load on the branch circuit, both no load and load conditions were tested and are recorded.

3. Fixture wire insulation - 150 to 200°C maximum. Fixture wire is normally rated for 150°C maximum and was so rated for fixtures B and C. Fixture A uses wire rated for 200°C maximum.

4. Fixture enclosure - 150°C maximum. According to the Underwriters' Laboratory Standard for Safety for Electric Lighting Fixtures, UL57, August 15, 1977, no point on the outside of a recessed lighting fixture enclosure should exceed 150°C in temperature."

Comments

Increasing barrier height is one possible method of providing safe operating conditions for closed-top barriers; however, this would increase heat loss at that point and increase the risk of condensation.

Reference No.	6.1.3.7
Title	Operating Temperatures for a Convectively-Cooled Recessed Incandescent Light Fixture
Author(s)	D.W. Yarbrough and I. Toor
Publisher/Date/Pages	Oak Ridge National Laboratory/September 1980
Available from/Price	Oak Ridge National Laboratory Oak Ridge, Tennessee
Catalogue & Indexing Numbers	ORNL/SUB-7715/1
Key Words	Recessed light fixture/thermal insulation/electrical wiring
Sector Applicability	Office Residential Restaurants Industrial Retail

Abstract

"Test results are given in this report for the operation of a recessed incandescent light fixture intended for residential use. The fixture which has been designed and marketed by Thomas Industries, Inc. is labelled for use in direct contact with attic thermal insulation. Temperature control of the powered fixture is provided by convective heat transfer from the ceiling side of the fixture.

The fixture was operated at power levels up to two times the rated power of 75 watts and under thermal insulations up R-40. In all operating configurations tested the fixture surface in contact with attic insulation was found to be less than 175°C. The observed surface temperatures are judged to be safe for operation in contact with loose-fill or batt-type insulations.

It was observed that the power leads inside one fixture configuration are exposed to temperatures as high as 168°C. The electrical insulation could, therefore, have a limited life. The properties of the internal fixture wiring were not, however, studied in detail."

Comments

The authors judge the observed fixture surface temperatures "safe for operation with loose fill fiberglass, rock wool, or cellulose insulation or insulating batts". The surface temperature of 175°C observed for some of the fixture configurations would not be considered acceptable according to the Canadian Electrical Code requirement which states that "every recessed luminaire shall be so installed that adjacent combustible material is not subjected to temperatures in excess of 90°C." (Section 30-308(2)).

Reference No.	**6.1.3.8**
Title	**Private Communication**
Author(s)	**K. Kameoka**
Publisher/Date/Pages	Canadian Standards Association/March 1982
Available from/Price	N/A
Catalogue & Indexing Numbers	N/A
Key Words	Recessed light fixtures/thermal insulation/test method development
Sector Applicability	Office Residential Restaurants Industrial Retail

Abstract

This memorandum outlines the test method development by a Canadian Standards Association ad-hoc committee on lighting fixtures that determines the "Thermal Characteristics of Recessed fixtures when Blanketted with Loose Insulation". The study considers the effect of increasing thermal insulation thicknesses on the surface temperature of a simulated recessed light fixture containing a 150 W incandescent lamp. From the results of the tests the ad-hoc group recommends that a 15 cm thickness of insulation be considered sufficient to represent any future amount of insulation which may be added to an existing installation.

Reference No.	6.1.3.9
Title	Insulation May Cause Wiring Code Violations
Author(s)	Electrical World
Publisher/Date/Pages	Electrical World/November, 1981
Available from/Price	Electrical World
	Refer to 6.1.2.3

Reference No.	6.1.3.10
Title	Handbook on Insulating Homes for Energy Conservation
Author(s)	Canadian General Standards Board
Publisher/Date/Pages	Canadian General Standards Board/1980
Available from/Price	Canadian General Standards Board Hull, Quebec K1A 0S5 $28.00

Refer to 6.2.4.3

6.1.4 Electrical Receptacles and Switches

Reference No.	6.1.4.1
Title	Effects of Thermal Insulations on Electrical Connections and Outlet Boxes
Author(s)	Robert W. Beausoliel, James R. Clifton, William J. Meese
Publisher/Date/Pages	U.S. National Bureau of Standards/April 1981/52 pgs
Available from/Price	National Technical Information Service Springfield, VA. 22161 $8.00
Catalogue & Indexing Numbers	NBSIR81-2220
Key Words	Cellulose thermal insulation/corrosion of electrical outlet boxes and devices/electrical devices/ humidity, thermal insulation and corrosion of electrical wiring/shock hazards/urea-formalhyde thermal insulation
Sector Applicability	Office Residential Restaurants Industrial Retail

Abstract

"When residential walls are retrofitted with "foamed-in" urea formaldehyde or "blown-in" cellulose thermal insulations, the insulation may enter electrical outlet and switch boxes. The effects of these thermal insulations on the durability of electrical components were studied. These studies were carried out at 44, 75, and 96% relative humidites with test periods between one and twelve months.

Laboratory test methods were developed and tests performed to determine the electrical and corrosive effects of urea formaldehyde and cellulose thermal insulation contained in electrical outlet and switch boxes. The boxes were tested in humidity-controlled closed-glass vessels at ambient temperatures. These tests were of an exploratory nature and did not cover all of the conditions that would exist in a residential wall. The testing methods are described in this report and the results are presented and interpreted.

Results indicate that these thermal insulations can cause significant corrosion of electrical components and can cause shock hazards and increased energy losses. It is concluded that these thermal insulations should be removed from electrical outlet and switch boxes."

Comments

This exploratory study assumed that condensation in the walls of older retrofitted homes and new homes could be a potential problem because of air leakage through electrical penetrations and plumbing stacks. Although a literature review by the National Bureau of Standards did not reveal any definitive cases of condensation within wall outlets, it was suggested that "the occurrence of condensation within outlet boxes was probable".

A useful method for determining the corrosion rate of the metallic components in electrical devices was presented in this report. This involved measurement of corrosion currents between the energized conductor (black wire) and the ground wire of the various electrical devices tested. Observation of the experiments indicated that "visually ascertained corrosion results were in agreement with measured corrosion current trends". It should be noted that corrosion currents were measured only in cellulose-filled outlets exposed to 96 and 75% relative humidities and only in urea-formaldehyde foam-filled outlets exposed to 96% relative humidity.

Shock hazard assessment was based on an American National Standard ANSI C39.5-1974. Only those insulation-filled and ungrounded outlet boxes with metal flush plates that were exposed to 96% relative humidity resulted in potential for shock hazards.

6.1.5 Electrical Outlet and Junction Boxes

Reference No.	6.1.5.1
Title	Residential Non-metallic Electrical Outlet Boxes Literature Review
Author(s)	S.J. Oda
Publisher/Date/Pages	Ontario Hydro Research Division/March 1980
Available from/Price	Ontario Hydro Research 800 Kipling Ave Toronto, Ontario M8Z 5S4
Catalogue & Indexing Numbers	Ontario Hydro Research Report No. 80-127-K
Key Words	Outlet boxes/flammability/plastic/overheating/ receptacles/electrical fire
Sector Applicability	Office Residential Restaurants Industrial Retail

Abstract

This report reviews available literature on non-metallic outlet boxes with respect to their mechanical and flammability properties A comparison of data on metallic and non-metallic boxes includes differences in electrical fault containment, protection against installation damage and internal and external heat resistance.

Reference No.	6.1.5.2
Title	Exploratory Study of Temperatures Produced by Self-Heating of Residential Branch Circuit Wiring When Surrounded by Thermal Insulation
Author(s)	R.W. Beausoliel, W.J. Meese and L.S. Galowin
Publisher/Date/Pages	U.S. National Bureau of Standards/July 1978.
Available from/Price	National Technical Information Service Springfield, VA 22161

Refer to 6.1.2.1

Reference No.	6.1.5.3
Title	Effects of Thermal Insulations on Electrical Connections and Outlet Boxes
Author(s)	Robert W. Beausoliel, James R. Clifton, William J. Meese
Publisher/Date/Pages	U.S. National Bureau of Standards/April 1981/52 pgs
Available from/Price	National Technical Information Service Springfield, VA. 22161 $8.00

Refer to 6.1.4.1

Reference No.	6.1.5.4
Title	Effects of Thermal Insulation on the Reliability and Safety of Residential Electrical Wiring
Author(s)	S.J. Oda
Publisher/Date/Pages	Ontario Hydro Research Division/March 1981
Available from/Price	Ontario Hydro 800 Kipling Ave Toronto, Ontario M8Z 5S4

Refer to 6.2.1.5

Reference No.	6.1.5.5
Title	Reducing Infiltration Through Electrical Wall Outlets - Preliminary Report
Author(s)	R.L. Hicks
Publisher/Date/Pages	Ontario Hydro Research Division/February 1980
Available from/Price	Ontario Hydro Research Division 800 Kipling Ave Toronto, Ontario M8Z 5S4

Refer to 6.2.3.1

Reference No.	6.1.5.6
Title	Handbook on Insulating Homes for Energy Conservation
Author(s)	Canadian General Standards Board
Publisher/Date/Pages	Canadian General Standards Board/1980
Available from/Price	Canadian General Standards Board Hull, Quebec K1A 0S5 $28.00

Refer to 6.2.4.3

Reference No.	6.1.5.7
Title	Condensation in Electrically-Heated Houses
Author(s)	H.W. Orr
Publisher/Date/Pages	Division of Building Research/National Research Council of Canada
Available from/Price	Division of Building Research National Research Council of Canada Prairie Regional Station Saskatoon, Saskatchewan

Refer to 6.2.5.6

6.1.6 Electrical Overcurrent Protection

Reference No.	6.1.6.1
Title	Experimentally-Determined Performance of Some Residential Circuit Breakers
Author(s)	R. Beausoliel and W. Meese
Publisher/Date/Pages	U.S. National Bureau of Standards/April 1981
Available from/Price	National Technical Information Service Springfield, VA 22161
Catalogue & Indexing Numbers	NBSIR81-2221
Key Words	Branch circuits/circuit breaker/electrical fire/low ambient temperature/trip time
Sector Applicability	Office Residential Restaurants Industrial Retail

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Abstract

"Laboratory test results show that at low ambient temperatures some residential-type circuit breakers may not trip at currents up to 140% of rated currents. Under some environmental conditions this may lead to wiring temperatures that exceed the limitations specified in the National Electrical Code. The results also show that circuits sometimes open at the point of short circuits before circuit breakers operate. Ignition of combustibles proximate to the point of such short circuits sometimes occurs."

Comments

The circuit breakers tested in this U.S. exploratory study were rated at 20 A. In Canada, 15 A circuit breakers are more commonly used for overcurrent protection of branch circuits.

The authors suggest further study to include "laboratory studies of generic types of residential overcurrent devices" with sufficient sample size for statistical validity.

Reference No.	6.1.6.2
Title	Handbook on Insulating Homes for Energy Conservation
Author(s)	Canadian General Standards Board
Publisher/Date/Pages	Canadian General Standards Board/1980
Available from/Price	Canadian General Standards Board Hull, Quebec K1A 0S5 $28.00

Refer to 6.2.4.3

6.1.7 Mathematical Modeling

Reference No.	6.1.7.1
Title	Modeling for Determination of Temperatures of Electrical Cables Within Thermally Insulated Walls (Interim Report)
Author(s)	David D. Evans
Publisher/Date/Pages	U.S. National Bureau of Standards/October 1980
Available from/Price	National Technical Information Service Springfield, VA 22161
Catalogue & Indexing Numbers	NBSIR80-2129
Key Words	Electric wiring/thermal insulation/electric cables - thermal properties
Sector Applicability	Office Residential Restaurants Industrial Retail

Abstract

Models have been developed to predict the temperature rise caused by resistive heating of a current-carrying electric cable within an insulated wall cavity, with emphasis on simplified models to minimize computation time. Predictions are compared to measurements performed on a 2-12 AWG NM cable installed in a laboratory wall space mock-up. Results of the two-dimensional model are within 15% of the measured temperatures. The heat sink effect of the wood studs within the wall on the temperature rise of the section of cable passing through them is demonstrated both with experiment and calculation. (For 2 -12 AWG NM cable carrying 20 A load, calculations show that conduction of heat along the wire to the wood studs lowers the steady operating temperature at least 5°C, compared to the operating temperature when no heat is dissipated parallel to the cable direction).

Reference No.	6.1.7.2
Title	Calculated Operating Temperatures of Thermally-Insulated Electric Cables
Author(s)	David D. Evans
Publisher/Date/Pages	U.S. National Bureau of Standards/January 1981
Available from/Price	National Technical Information Service Springfield, VA 22161
Catalogue & Indexing Numbers	U.S. NBS Technical Note 1133
Key Words	Electric cable/electrical fire/models/thermal insulation/wiring system
Sector Applicability	Office Residential Restaurants Industrial Retail

Abstract

Steady-state operating temperatures of current-carrying electrical cable buried axially in cylinders of thermal insulation were calculated. Combinations of six types of non-metallic electric cable, two thermal insulations, five thermal insulation thicknesses, and a range of currents both greater and less than the typical rated service currents for the cables were studied. Cable sizes included 2 - 14 AWG, 2 - 12 AWG, and 2 - 10 AWG copper; 2 - 4 AWG, 2 - 6 AWG, 2 - 8 AWG aluminum.

The two thermal insulations, selected to give a wide range of insulation conductivities, were a 11 kg/m^3 density glass fibre loose fill and a high density mineral fibre pipe insulation. Insulation thickness were 0, 2.5, 5, 10 and 20 cm and electrical currents were 15, 20, 30, 40, and 55 A.

Predictions show that the temperature of electric cables can exceed the 60°C temperature limit for jacket materials (U.S. requirement) with a 5 cm thick layer and often just a 2.5 cm thick layer of insulation wrapped circumferentially around the cable.

Comments

The report suggests that the upper temperature limit of the cable jackets could be exceeded if the rated loads were maintained long enough to approach steady-state conditions. For cables operated for an extended period of time above rated current, conductor temperatures may be sufficient to induce ignition of combustible insulation materials.

Reference No.	6.1.7.3
Title	Effects of Thermal Insulation on the Reliability and Safety of Residential Electrical Wiring
Author(s)	S.J. Oda
Publisher/Date/Pages	Ontario Hydro Research Division/March 1981
Available from/Price	Ontario Hydro 800 Kipling Ave Toronto, Ontario M8Z 5S4

Refer to 6.2.1.5

6.2. Thermal Upgrading Measures

6.2.1 Thermal Insulations

Reference No.	6.2.1.1
Title	Conductors Installed in Foam Insulation
Author(s)	Lawrence O. Smith
Publisher/Date/Pages	Department of Electrical Engineering, University of Manitoba/March 1978
Available from/Price	-
Catalogue & Indexing Numbers	-
Key Words	Urea formaldehyde foam/electrical wiring
Sector Applicability	Office Residential Restaurants Industrial Retail

Abstract

The use of urea-formaldehyde foam insulation (UFFI) in walls was tested to determine its effect on electrical wiring. The tests showed that, in most common circumstances, foam insulation does not cause conductors to be heated above the temperature rating of their insulation (60°C). In less frequent situations, such as where the ambient temperature is high, the walls are very thick, or the circuit is overloaded, the rated temperature of the conductor insulation would be exceeded. It is recommended that further studies on foam insulation be done to investigate conductors in those less common situations.

Comments

This thesis project provides experimental data concerning the effect of electrical load and thermal insulation thickness on the temperature rise of electrical cables (NMD-3 and NMD-7) in UFFI-insulated wall sections. It was one of the first studies to indicate that the wood studs could provide an effective heat sink for the cables as compared to surrounding thermal insulations.

Reference No.	6.2.1.2
Title	A Preliminary Study of the Fire Safety of Thermal Insulation for Use in Attics or Enclosed Spaces in Residential Housing
Author(s)	Daniel Gross
Publisher/Date/Pages	U.S. National Bureau of Standards/July 1978
Available from/Price	National Technical Information Service Springfield, VA 22161
Catalogue & Indexing Numbers	NBSIR78-1497
Key Words	Cellulose fibre/mineral fibre/fire tests/ residences/smouldering/electrical devices/recessed fixtures
Sector Applicability	Office Residential Restaurants Industrial Retail

Abstract

This study evaluated the flammability requirements for cellulose and mineral fibre insulations and includes an analysis of standard flammability tests. A review of fire statistics indicated that "extensive data on the contribution of thermal insulations to fires, was not available". Laboratory mockups of 150 W recessed fixtures covered by cellulose fibre caused smouldering ignition in 7 of 8 cellulose samples.

Reference No.	6.2.1.3
Title	The National Program Plan for Building Thermal Envelope Systems and Insulating Materials.
Author(s)	P.R. Achenbach
Publisher/Date/Pages	U.S. Department of Energy/January, 1979
Available from/Price	National Technical Information Service Springfield, VA 22161
Catalogue & Indexing Numbers	DOE/CS-0059
Key Words	Light fixtures/junction boxes/wiring/chemical effects/thermal insulation
Sector Applicability	Office Residential Restaurants Industrial Retail

Abstract

This plan includes a section on the effects of thermal insulation on electrical systems and suggests specific projects to determine these effects. Projects include:

(1) Field studies of loading in existing residential electrical systems and extent of degradation of existing insulation,

(2) Study of barriers required adjacent to wiring and associated devices to provide for heat dissipation,

(3) Preparation of guidelines for DOE for retrofitting existing buildings with insulation,

(4) Determination of permissible blanketing of wiring elements and recessed light fixtures in new construction,

(5) Study of gas emissions, accelerated deterioration of insulation, degradation of chemical compounds in relation to operating temperatures of electrical insulations,

(6) Study of the chemical attack on electrical components by fire retardants under the moisture conditions likely to prevail in residential construction,

(7) Development of analytical models for heat transfer from blanketed wiring and recessed light fixtures with and without adjacent heat sinks such as wood joists.

Comments

This paper provides a comprehensive overview of thermal insulating materials and building thermal envelopes. Many of the specific project suggestions became the basis for further study at the U.S. National Bureau of Standards.

Reference No.	6.2.1.4
Title	Electrical Wiring - Staying on the Safe Side
Author(s)	Gail Porter
Publisher/Date/Pages	U.S. National Bureau of Standards, Dimensions/ October 1980
Available from/Price	U.S. National Bureau of Standards
Catalogue & Indexing Numbers	Dimensions/October 1980
Key Words	Residential construction/electrical wiring system/ thermal insulation/
Sector Applicability	Office Residential Restaurants Industrial Retail

Abstract

This article summarizes National Bureau of Standards' involvement in research projects concerned with the safety and performance of major electrical wiring components. Included in this summary are the effects of loose connections on device safety, the extent of overfusing in the residential building sector, the overcurrents allowed by some circuit breaker systems, the effect of thermal insulation surrounding current carrying wires, the effect of thermal insulation on the wiring of surface-mounted and recessed lighting fixtures; and, the corrosive effect of thermal insulations on electrical connections and junction boxes.

Comments

For more information on the National Bureau of Standards studies mentioned in this article, consult references 6.1.2.1, 6.1.3.5, 6.1.3.6, 6.1.4.1, 6.1.6.1, 6.3.1.1 and 6.4.4.

Reference No.	6.2.1.5
Title	Effects of Thermal Insulation on the Reliability and Safety of Residential Electrical Wiring
Author(s)	S.J. Oda
Publisher/Date/Pages	Ontario Hydro Research Division/March 1981
Available from/Price	Ontario Hydro 800 Kipling Ave Toronto, Ontario M8Z 5S4
Catalogue & Indexing Numbers	Ontario Hydro Research Report No 80-520-K
Sector Applicability	Office Residential Restaurants Industrial Retail

Abstract

A representative selection of the classes and forms of thermal insulations used in retrofit applications in residential construction is listed. Standard and special test methods and acceptance criteria are used to assess the effect of insulations on electrical wiring and associated devices. Laboratory testing of selected materials indicated the potential corrosivity of certain insulations; however, their exposure to a severe environment in a test enclosure did not produce any significant effect on the reliability or safety of the wiring system that could be attributed to the insulations. A mathematical model relating conductor temperature with insulation thickness and electrical current is presented.

Comments

(1) The 60°C rating of NMD-3 type wiring is exceeded when the wiring is surrounded by thermal insulation thicknesses $>R_{SI}$-3.5.

(2) The thermal insulations studied did not affect the mechanical or electrical properties of either insulated or bared electrical conductors. The results, however, were based on only one set of test conditions and should not be generalized to cover all conditions.

Reference No.	6.2.1.6
Title	The Super-Insulated Retrofit Book
Author(s)	R. Argue, B. Marshall
Publisher/Date/Pages	Renewable Energy in Canada/1981
Available from/Price	Renewable Energy in Canada 107 Amelia St Toronto, Canada M4X 1E5 $11.95
Catalogue & Indexing Numbers	N/A
Key Words	Gasket/outlets/retrofit/recessed lights/caulking
Sector Applicability	Office Residential Restaurants Industrial Retail

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Abstract

This book for transforming existing residential construction into "super-insulated airtight" houses is divided into Primer, Manual (step-by-step instructions for interior and exterior retrofit), Survey (selective examples) and Appendix sections. It includes practical examples for sealing electrical outlets such as foam gaskets, polyethylene pans, or, if major interior renovation is undertaken, on the inside of the air barrier (ie, "double wall" system).

Removal of recessed fixtures is recommended to prevent excessive heat loss and eliminate potential fire hazards. Surface-mounted fixtures are suggested as replacements.

Reference No	6.2.1.7
Title	Effects of Thermal Insulation on Knob and Tube Wiring
Author(s)	S.J. Oda
Publisher/Date/Pages	Ontario Hydro Research Division/March 1978
Catalogue & Indexing Numbers	Ontario Hydro Research Report No. 78-96-K

Refer to 6.1.1.1

Reference No.	6.2.1.8
Title	Effects of Installation of Thermal Insulating Materials on Knob and Tube Wiring in Old Residential Structures
Author(s)	R.L. Pescatore
Publisher/Date/Pages	Progress Report by Underwriters Lab Inc. (Santa Clara, CA) to Pacific Gas and Electric (San Francisco, CA)/March 1978
Available from/Price	N/A

Refer to 6.1.1.2

Reference No.	6.2.1.9
Title	Performance of Loose Fill Cellulose Fibre and Polystyrene Foam Insulations over Knob and Tube Wiring
Author(s)	S.J. Oda
Publisher/Date/Pages	Ontario Hydro Research/September 1978
Available from/Price	Ontario Hydro Research Division 800 Kipling Ave Toronto, Ontario M8Z 5S4

Refer to 6.1.1.3

6.2.2 Sealants and Caulking Compounds

Reference No.	6.2.2.1
Title	Effect of Sealant Compounds on Electrical Wires
Author(s)	A. Blaga and R. Lacroix
Publisher/Date/Pages	National Research Council of Canada/December 1979
Available from/Price	Division of Building Research National Research Council of Canada Montreal Rd., Ottawa, Ontario K1A OR6
Catalogue & Indexing Numbers	NRC Building Research Note No. 152
Key Words	Sealing and caulking/electrical wiring/chemical effects
Sector Applicability	Office Residential Restaurants Industrial Retail

Abstract

Five types of commercial sealant materials used to seal vapour barriers around electrical penetrations were tested on seven different residential electrical cable sets to determine their effect on electrical insulation resistance. One end of each cable was covered with sealant so as to be in contact with insulation, sheathing, jacketing and bare ground wire. No significant change in either electrical insulation appearance or insulation resistance was produced after 65 days of aging under standard laboratory conditions (25°C, 50% relative humidity).

Comments

This study gives preliminary experimental data for the effect of sealants on cables for one set of conditions and, as such, should not be generalized to cover all possible conditions. In addition, the study did not cover older types of cable such as NMD-1, NMD-3 or aluminum conductors.

The following sealants were investigated:

1 component polysulphide (chemical curing)
1 component acrylic (solvent cure)
1 component silicone (chemical cure)
1 component polysulphide (chemical cure)
Butyl-Polyisobutylene base (solvent curing)

The following cables were tested:

Two NMD-7, 14 AWG Copper/2 cdr, Nylon sheathing, PVC jacket
One NMD-7, 14 AWG Copper/3 cdr, Nylon sheathing, PVC jacket
One NMD-7, 12 AWG Copper/2 cdr, Nylon sheathing, PVC jacket
One NMD-7, 14 AWG Copper/2 cdr, brown paper sheath, bitumen-impregnated jacket
One NMW-10, 12 AWG Copper/2 cdr, Nylon sheath, PVC jacket
One NMD-7, 12 AWG Copper/2 cdr, Brown paper sheath, PVC jacket.

Reference No.	6.2.2.2
Title	The Super-insulated Retrofit Book
Author(s)	R. Argue, B. Marshall
Publisher/Date/Pages	Renewable Energy in Canada/1981
Available from/Price	Renewable Energy in Canada 107 Amelia St Toronto, Canada M4X 1E5 $11.95

Refer to 6.2.1.6

6.2.3 Gaskets and Weatherstripping

Reference No.	6.2.3.1
Title	Reducing Infiltration Through Electrical Wall Outlets - Preliminary Report
Author(s)	R.L. Hicks
Publisher/Date/Pages	Ontario Hydro Research Division/February 1980
Available from/Price	Ontario Hydro Research Division 800 Kipling Ave Toronto, Ontario M8Z 5S4
Catalogue & Indexing Numbers	Ontario Hydro Research Report No. 79-612-K
Key Words	Electrical outlet/infiltration/gasket/prefabricated vapour barrier
Sector Applicability	Office Residential Restaurants Industrial Retail

Abstract

This report describes an exploratory study on methods to seal electrical outlets against air leakage. Measurements were made using five methods:

(1) Installation of polyethylene sheet around outlets as per Ontario Hydro requirements,
(2) Blocking the outlet box holes with electrical tape,
(3) Use of a commercially-available gasket behind the coverplate (does not block receptacle openings),
(4) Use of a commercially-available box-type prefabricated vapour barrier,
(5) Clear plastic tape over receptacle openings (not usable)

Comments

The results of air flow measurements showed a wide range in reduction of airflow from a factor of 8 for method (2) to a factor of 2 for method (3).

The author suggests further study on the effect of installation workmanship and effect of prolonged exposure to drafts before making any statements on the effectiveness of the methods in actual construction practice.

6.2.4 Installation Practices

Reference No.	6.2.4.1
Title	Material Criteria and Installation Practices for the Retrofit Application of Insulation and Other Weatherization Materials - A Technical Report
Author(s)	U.S. Department of Energy
Publisher/Date/Pages	U.S. Department of Energy/November 1978
Available from/Price	N/A
Catalogue & Indexing Numbers	DOE/CS0051
Key Words	Thermal insulation/installation practices/electric wiring/electric devices
Sector Applicability	Office Residential Restaurants Industrial Retail

Abstract

Material criteria are presented to assist manufacturers, installers and consumers in selecting materials for retrofitting residential buildings in a manner which will guard, to the maximum extent possible, the safety of the occupants and the effectiveness of the measures installed. Installation practices are given for the retrofit materials involved with the exception of caulks, sealants and weatherstripping materials.

Comments

This draft report prepared by the Building and Community Systems Division of the Department of Energy reviewed material criteria and installation practices for insulation and other weatherization materials. Based on the potential for overheating branch circuits in the ceiling space the report considered including the following in DOE Installation Practices:

"(1) Insulation should be in a ceiling up to the underside of wiring with an open air space above such wires,
(2) Insulation installed only in ceiling sections with no perpendicular or parallel wiring in the joist areas,
(3) Insulation in the ceiling should have barriers round and below the sides of wiring in excess of the height of the insulation. The barrier should form an air space to permanently restrain insulation from covering the wiring."

In view of the strong emphasis on energy conservation measures and the lack of sufficient laboratory and field data on the extent of any problems, these requirements did not appear practical and a search for alternate solutions was recommended.

Reference No.	6.2.4.2
Title	Criteria for the Installation of Energy Conservation Measures
Author(s)	H.R. Trechsel, S.J. Launey
Publisher/Date/Pages	U.S. National Bureau of Standards/July 1981/203 pgs
Available from/Price	Superintendent of Documents U.S. Government Printing Office Washington, D.C. 20402 $6.00
Catalogue & Indexing Numbers	NBS SP606
Key Words	Automatic ignition devices/caulks/effectiveness/ energy conservation/energy conservation measures/ installation/insulation/oil burners/practices/ safety/sealants/standards/strom doors/storm windows/vent dampers/water heaters/windows
Sector Applicability	Office Residential Restaurants Industrial Retail

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Abstract

This study describes standard installation practices developed to assist in assuring the effectiveness and safety of energy conservation measures installed under the Residential Conservation Service of the U.S. Department of Energy (DOE). The criteria are being used by DOE to develop training manuals for installers, inspectors and energy auditors. The report is divided into two parts:

Part I provides information on the intended use of the practices, outlines the RCS program, and discusses specific major technical and related issues that were considered in the development of the standards: moisture and building retrofit, attic ventilation, electrical wiring, recessed and surface-mounted fixtures, the use of diagnostic tools (infrared thermography, air change rate, and window air leakage measurements), and product certification.

Part II provides the actual practices together with commentary and additional recommendations. The products covered are loose-fill, batts and blankets, rigid foam boards, UF foam and reflective insulations, window devices, caulks and sealants, water heater insulation, oil burner replacements, and vent dampers.

Comments

Part I of this study deals with the interaction of the wiring system and thermal upgrading. Concerning the electrical wiring, the authors suggest from their review of technical data (primarily from NBS studies) that "temperature levels and their duration observed for residential branch circuits with properly matched overcurrent protection do not seem to constitute significant hazards". However, they state further "the electrical insulation could experience a long term degradation and reduced service life". With incorrectly matched overcurrent protection (ie, overfusing) "elevated temperatures could exist for sufficient duration to cause melting and possible ignition of electrical insulation" and initiate smouldering in existing combustible insulations (ie, untreated paper or wood shavings).

For older "code grade rubber" wiring (installed before 1940) with a temperature rating of 50°C, laboratory tests showed that the rating would be exceeded in less than one-half hour when the wire is surrounded by thermal insulation. For houses with this type of wiring, the authors recommend an inspection of the wiring by an approved electrician and an upgrading of the electrical service or derating of circuits prior to installing thermal insulation over the wiring.

The installation of loose fill cellulose or foamed-in-place insulations in wall stud spaces can result in penetration of the materials into electrical boxes. The authors recommend an inspection of the boxes and removal of any insulation to alleviate potential hazards. Prior to the inspection, the relevant circuit should be de-energized.

The authors reviewed test results of NBS studies on recessed light fixtures and conclude that properly installed open topped barriers "allow these fixtures and associated branch circuit wiring to operate within their specified temperature ratings". Any deviation from this practice such as covering of the barrier, overlamping of the fixture, or reduction of the 75 mm spacing between fixture enclosure and thermal insulation, will cause branch circuit wiring to exceed its rating (60°C). Installation of surface-mounted fixtures is treated similarly, in that the same enclosures as are used for recessed fixtures are recommended around the ceiling boxes used for surface-mounted fixtures.

Reference No.	6.2.4.3
Title	Handbook on Insulating Homes for Energy Conservation
Author(s)	Canadian General Standards Board
Publisher/Date/Pages	Canadian General Standards Board/1980
Available from/Price	Canadian General Standards Board Hull, Quebec K1A 0S5 $28.00
Catalogue & Indexing Numbers	CGSB 51-GP-42MP
Key Words	Light fixtures/electrical panel/electrical wiring/ retrofit/new construction
Sector Applicability	Office Residential Restaurants Industrial Retail

Abstract

"This handbook describes the reinsulation of existing homes and the insulation of new homes for the purpose of reducing their winter heating requirements and thereby conserving energy. The handbook contains basic and theoretical knowledge on home energy use, heat transmission and moisture flow as well as practical knowledge on building construction, sealing air leaks and the insulation of walls, ceilings and basements. Insulation materials, health and safety considerations and the determination of reinsulation properties are also discussed."

Comments

This manual is a comprehensive manual for professionals involved in the reinsulation of existing homes and the insulation of new homes. Among the recommendations for those involved in reinsulation in attic spaces, the manual suggests inspection of all electrical fixtures and suspect wiring to prevent fire hazards and removal of recessed lighting fixtures or the installation of protective barriers around the fixtures. (The latter suggestion is not the recommended procedure since that portion of the attic will be uninsulated and will be subject to heat loss and condensation problems).

Regarding the insulation of the inside of the foundation in both existing and new basements, the manual suggests that "the main electrical panel could be framed and insulated with a hinged panel providing access. Careful caulking and weatherstripping will be required to prevent condensation problems".

The "new wall designs" section illustrates a good example of a "double" wall system that places the vapour barrier within the wall and allows the wiring and devices to be installed between the vapour barrier and the interior finish and avoid unnecessary penetration of the barrier.

Reference No.	6.2.4.4
Title	The Super-insulated Retrofit Book
Author(s)	R. Argue, B. Marshall
Publisher/Date/Pages	Renewable Energy in Canada/1981
Available from/Price	Renewable Energy in Canada 107 Amelia St Toronto, Canada M4X 1E5 $11.95

Refer to 6.2.1.6

6.2.5 Field Studies

Reference No.	6.2.5.1
Title	Minnesota Retrofit Insulation In-situ Test Program
Author(s)	S. Spinney and J. Weidt
Publisher/Date/Pages	Minnesota Energy Agency/May 1978
Available from/Price	Minnesota Energy Agency St. Paul, Minnesota
Catalogue & Indexing Numbers	-
Key Words	Field survey/armoured cable/knob and tube wiring/junction boxes/outlet boxes
Sector Applicability	Office Residential Restaurants Industrial Retail

Abstract

This field study of 22 wall and 48 ceiling insulation samples determines the thermal performance of the materials in situ and their compatibility with the structural and wiring components. Electrical components included flexible metal conduit, ceiling junction boxes behind surface mounted lights and knob and tube wiring. No evidence of degradation of any of these components due to the retrofit insulation was observed.

Comments

According to the authors the test results are not statistically valid due to the small sample size. The report should be used as a basis for further field studies.

Reference No.	6.2.5.2
Title	A Field Study of Moisture Damage in Walls Insulated Without A Vapor Barrier
Author(s)	George A. Tsongas, F. Glen Odell, James C. Thompson
Publisher/Date/Pages	Proc. ASHRAE/DOE Conference "Thermal Performance of Exterior Envelopes of Buildings"/December 1979
Available from/Price	American Society of Heating, Refrigeration and Air-Conditioning Engineers
Catalogue & Indexing Numbers	ASHRAE SP28
Sector Applicability	Office Residential Restaurants Industrial Retail

Abstract

This paper describes results of a study to determine whether adding wall insulation without a vapor barrier can increase the risk of moisture damage within the walls. The exterior walls of 96 homes in Portland, Oregon were opened, of which 71 had retrofitted insulation (3 types) and 25 were uninsulated. Field and laboratory test results are presented which show the absence of moisture accumulation and wood decay fungi, or other indications of moisture damage in the walls of the test homes.

Comments

Of the 96 homes in the study, 82 had ducted heating systems (27 gas, 52 oil) and the remaining 14 were primarily electrically heated with no ducting. It was anticipated that at the end of the study prior to opening any walls, some indication of moisture damage including "corrosion of wire and leaks around electrical connections" would be observed. Corrosion of wire and nails occurred in approximately 1% of the homes while leaks around water, sewer and electrical openings occurred in 11% of the homes. The authors conclude that moisture damage is not a problem in homes retrofitted with wall insulation (at least in the western region of the Pacific Northwest) but that further study is required to determine the cost effectiveness of adding wall insulation.

Reference No.	6.2.5.3
Title	Field Investigation of the Performance of Residential Retrofit Insulation
Author(s)	John J. Weidt, Robert J. Saxler, and Walter Rossiter Jr.
Publisher/Date/Pages	U.S. National Bureau of Standards/September 1980
Available from/Price	National Technical Information Service Springfield, VA 22161
Catalogue & Indexing Numbers	NBS Technical Note 1131
Key Words	Conservation/energy/field survey/insulation/moisture content/residences/retrofit/thermal resistivity
Sector Applicability	Office Residential Restaurants Industrial Retail

Abstract

A study was conducted to obtain information on the performance of four types of thermal insulation installed in the exterior walls of 39 houses. No observations were recorded to indicate that the addition of insulation had adversely affected the wall components for the 2-month exposure. The few electrical junction boxes or other metal components found in five of the houses were in good condition and corrosion, if any, was minimal.

Comments

Field observations indicated the presence of insulation in a few of the electrical outlet and switch boxes, however, the number of observations was limited. Electrical connections in junction boxes found to contain thermal insulation were not inspected for corrosion. The authors recommend further studies to determine the effect of insulation on the corrosion of metals in service.

Reference No.	6.2.5.4
Title	Electrical Aspects of the CSA/NBS Weatherization Study
Author(s)	Marianne P. Vaishav
Publisher/Date/Pages	U.S. National Bureau of Standards/January 1981/ 20 pgs
Available from/Price	National Technical Information Service Springfield, VA 22161
Catalogue & Indexing Numbers	NBSIR81-2203
Key Words	Branch circuit wiring problems/fuse, circuit breaker panel problems/electrical problems/electrical wiring system/extension cord wiring/overamping/residential structures/safety/thermal insulation
Sector Applicability	Office Residential Restaurants Industrial Retail

Abstract

Technical inspections performed by electrical experts on 157 homes indicate that electrical deficiencies appeared to be present in 78% of the homes. Deficiencies included: incorrect overcurrent protection (overfusing), temporary and/or extension cord wiring, lighting system problems, branch circuit problems, fuse/circuit breaker problems, and service entrance panel problems. Further investigations are suggested to determine the magnitude of the problems and the remedial actions that might be required.

Comment

This paper contains three useful appendices:

(1) Potential Electrical Hazards in Housing for "Non-Technical" Data Collection.

(2) Detailed Electrical Inspection conducted as a result of problems in (1).

(3) Examples of technical inspections performed on CSA survey houses.

The author suggests that the condition of any suspect electrical insulation could be aggravated during the installation of additional insulation simply by moving the wiring. Baring of the conductors could occur and create a potential hazard.

Reference No.	6.2.5.5
Title	Field Measurement of Branch Circuit Wire Temperatures
Author(s)	Thomas Faison
Publisher/Date/Pages	U.S. National Bureau of Standards/September 1981
Available from/Price	National Technical Information Service Springfield, VA 22161
Catalogue & Indexing Numbers	NBSIR81-2347
Key Words	Branch circuit/electric wire/field measurements/ temperature excursions/thermal insulation
Sector Applicability	Office Residential Restaurants Industrial Retail

Abstract

"The National Bureau of Standards(NBS), under the sponsorship of the U.S. Department of Energy (DoE), planned and conducted a program to monitor temperature excursions of residential branch circuit wiring under field conditions. This program was conducted to develop a field data base needed to determine the prevailing conditions in the field and to respond to various assertions that the encapsulation of branch circuit wiring within thermal insulation is a potential hazard. It has been demonstrated through previous laboratory investigations that buried wires, when operated continuously at rated ampacity, will exceed the thermal limit established by the National Electrical Code (NEC). Approximately 2,800 circuits in 667 residences were monitored through a volunteer program with the utilities. The results of the study show that slightly more than one-third of the circuits monitored operated at or above the thermal limit established by the NEC, 60°C (140°F). Thermal distributions are shown for variables such as: region, season, and age."

Comments

This pilot study determined the percentage of monitored circuits with temperatures above the 60°C limit but not the length of the exposure. Approximately 10% of the temperature sensors were applied incorrectly on or above the thermal insulation, observations made in the study include the following:

(1) Of the 167 residences that returned information on overcurrent protection, 64 had at least one circuit with an oversized circuit breaker or fuse (37%).

(2) Age of the wiring did not influence observed thermal distribution (average age of wiring was 13 years).

(3) Regional biases in the data acquisition could have occurred because volunteering electrical utilities happened to be located primarily in the eastern half of the U.S.

Reference No.	6.2.5.6
Title	Condensation in Electrically-Heated Houses
Author(s)	H.W. Orr
Publisher/Date/Pages	Division of Building Research/National Research Council of Canada
Available from/Price	Division of Building Research National Research Council of Canada Prairie Regional Station Saskatoon, Saskatchewan
Catalogue & Indexing Numbers	N/A
Key Words	Electrically-heated houses/condensation/field survey/electrical penetrations
Sector Applicability	Office Residential Restaurants Industrial Retail

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Abstract

"Electrically-heated houses without chimneys experience serious attic condensation problems in cold climates. The use of humidity control devices, increased care in installing vapor barriers and more attic ventilation have not resolved the problem and special measures in sealing the house from the attic are indicated."

Comments

The 60 detached houses studied in this survey were located in Gillam, Manitoba with annual degree-days = 6100 for Winnipeg, 794 degree-days and a 2-1/2% January design temperature of -40°C.

The homes were experiencing heavy frost on roof gable ends and roof sheathing. Possible causes for this problem included:

(1) high indoor relative humidity (~40%) compared to an outside temperature of -35°C was possible because of well-insulated walls and ceilings and triple glazing,

(2) many more electrical penetrations than in conventionally-heated structures increasing leakage into the attic space,

(3) no chimneys and a fresh air intake in the basement lowered the neutral pressure plane and increased the potential for air leakage from the house into the attic,

(4) lower heat loss through the ceiling because of more effective insulation allowed the roof sheathing to become colder and combined with more moisture extraction from air that leaked into the attic resulted in more frost accumulation.

Reference No.	6.2.5.8
Title	Effects of Installation of Thermal Insulating Materials on Knob and Tube Wiring in Old Residential Structures
Author(s)	R.L. Pescatore
Publisher/Date/Pages	Progress Report by Underwriters Lab Inc. (Santa Clara, CA) to Pacific Gas and Electric (San Francisco, CA)/March 1978
Available from/Price	N/A

Refer to 6.1.1.2

6.3. Electrical Fires Involving Insulation

Reference No.	6.3.1.1
Title	Residential Electrical Wiring Systems and Thermal Insulation
Author(s)	Beatrice Harwood
Publisher/Date/Pages	U.S. Consumer Product Safety Commission (CPSC)/ August 1979
Available from/Price	U.S. Consumer Product Safety Commission Washington, DC 20207
Catalogue & Indexing Numbers	N/A
Key Words	Thermal insulation/electrical wiring/hazard/ electrical fires
Sector Applicability	Office Residential Restaurants Industrial Retail

Abstract

This report discusses the investigation by the U.S. Consumer Product Safety Commission of hazards associated with the use of thermal insulation over electrical wiring and devices. Included in the report is data from the U.S. Fire Administration and from field and laboratory studies that have a bearing on this problem.

Comments

This document provides an overview of the U.S. studies involving insulation and electrical wiring up to 1973. Preliminary data on circuit overfusing, temperature rise in cables surrounded by insulation and an analysis of actual fire reports is presented. This analysis of 58 fires involving electrical wiring and thermal insulation indicated that 14 were caused by either electrical overload or damaged wire insulation.

Reference No.	6.3.1.2
Title	Analysis of Fires Involving Thermal Insulating Materials
Author(s)	U.S. Consumer Product Safety Commission
Publisher/Date/Pages	U.S. Consumer Product Safety Commission/ December 1980/153 pgs
Available from/Price	U.S. Consumer Product Safety Commission
Catalogue & Indexing Numbers	N/A
Key Words	Thermal insulation/electrical fires/electrical wiring/light fixtures/residential construction
Sector Applicability	Office Residential Restaurants Industrial Retail

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Abstract

This report presents data collected between September 1978 and March 1980 on 99 residential fires involving thermal insulating materials. An analysis of the data indicates that fires involving thermal insulations are caused most often by direct contact of the materials with heat producing equipment (light fixtures, defective wiring, stove pipes), and result in smouldering, concealed fires. It is concluded that the single most common problem leading to fires involving thermal insulation is improper installation of the materials, even though the installation was done by professionals in the majority of cases.

Comments

Since the reports were prepared by local authorities in various jurisdictions (10 different states), the results are not statistically valid and should not be generalized to cover other conditions or populations.

Reference No.	6.3.1.3
Title	Energy conservation and Its Effect on Buildings from the Fire Protection Viewpoint
Author(s)	John G. Degenkolb
Publisher/Date/Pages	Fire Journal/May 1978
Available from/Price	N/A
Catalogue & Indexing Numbers	N/A
Key Words	Chemical and corrosive effects/thermal insulation/ electrical wiring/cellulose fibre/electrical fire
Sector Applicability	Office Residential Restaurants Industrial Retail

Abstract

This article expresses concerns over the potential adverse consequences that increased levels of insulation could have on the performance of electrical wiring and devices. The concerns included:

(1) Overheating during operation of electrical equipment;
(2) Overheating due to exothermic heat liberation during curing of thermal insulations [could be referring to polyurethane foam];
(3) Chemical interaction of electrical and thermal insulating materials;
(4) Chemically-induced corrosion;
(5) Increased difficulties of "rewiring" after some types of thermal insulating materials are installed.

Reference No.	6.3.1.4
Title	Limiting Safe Surface Temperatures for Combustible Materials
Author(s)	J.H. McGuire
Publisher/Date/Pages	Division of Building Research, National Research Council of Canada/November 1969
Available from/Price	National Research Council of Canada Montreal Rd., Ottawa, Ontario K1A OR6
Catalogue & Indexing Numbers	DBR NRCC Technical Paper No. 610
Key Words	Temperature limit/combustible materials/residential construction
Sector Applicability	Office Residential Restaurants Industrial Retail

Abstract

This paper discusses the selection of an appropriate temperature limit that adjacent combustible materials (wood) should be permitted to attain.

An upper limiting temperature of 100°C was chosen based on the postulation that generation of charcoal constitutes a hazard.

Reference No.	6.3.1.5
Title	Smouldering Initiation in Cellulosics under Prolonged Low-Level Heating
Author(s)	E.L. Schaffer
Publisher/Date/Pages	Fire Technology/February 1980
Available from/Price	Fire Technology Technomics Publications Stamford, Connecticut
Catalogue & Indexing Numbers	Fire Technology Vol. 16, No. 1, Feb 1980
Key Words	Smouldering fires/cellulose insulation/predictive model
Sector Applicability	Office Residential Restaurants Industrial Retail

Abstract

"Scant field information and the difficulty of conducting long-term research experiments on the low-level heating of cellulosics until ignition occurs have led to the advancement of an incipient smouldering ignition predictive model. One case suggests that initiation of smouldering combustion in untreated cellulosic insulations could be induced by one year of heating at 150°C."

Reference No.	6.3.1.6
Title	Fire Losses in Canada 1979 - Report of the Dominion Fire Commissioner
Author(s)	
Publisher/Date/Pages	Department of Supply and Services Canada 1981
Available from/Price	Department of Supply and Services Canada
Catalogue & Indexing Numbers	Cat. No. W51-19-19
Key Words	Fires/residential/electrical causes
Sector Applicability	Office Residential Restaurants Industrial Retail

Abstract

In 1979, fires in the "Residential" category accounted for 40,620 fires or 49% of the total fires reported in Canada. The electrical category (faulty equipment or wiring, short circuits, etc) caused 14,485 fires or 17% of the total. Although the 10-year average (1970-1979) of 13,436 electrical fires per year indicates a 7% increase in 1979, this increase corresponds to increased numbers from other fire causes.

Reference No.	6.3.1.7
Title	1979 and 1980 Fire Losses in Ontario
Author(s)	Office of the Fire Marshall Ministry of the Solicitor General Division of Public Safety
Publisher/Date/Pages	Office of the Fire Marshall Ministry of the Solicitor General Division of Public Safety
Available from/Price	Office of the Fire Marshall Ministry of the Solicitor General Division of Public Safety
Catalogue & Indexing Numbers	N/A
Key Words	Fires/residential/electrical causes
Sector Applicability	Office Residential Restaurants Industrial Retail

Abstract

In 1979, fires in the "Residence" property classification accounted for 12,510 fires or 47% of fires reported in Ontario. Fires from electrical causes were 16% of the total. These values are consistent with Dominion Fire Commissioner reports for Canada (6.3.1.6).

Reference No.	6.3.1.8
Title	Exploratory Study of Temperatures Produced by Self-Heating of Residential Branch Circuit Wiring When Surrounded by Thermal Insulation
Author(s)	R.W. Beausoliel, W.J. Meese and L.S. Galowin
Publisher/Date/Pages	U.S. National Bureau of Standards/July 1978.
Available from/Price	National Technical Information Service Springfield, VA 122161

Refer to 6.1.2.1

Reference No.	6.3.1.9
Title	A Preliminary Study of the Fire Safety of Thermal Insulation for Use in Attics or Enclosed Spaces in Residential Housing
Author(s)	Daniel Gross
Publisher/Date/Pages	U.S. National Bureau of Standards/July 1978
Available from/Price	National Technical Information Service Springfield, VA 22161

Refer to 6.2.1.2

6.4. New Construction

Reference No.	6.4.1
Title	Mark XI Energy Research Project - Summary of Results, 1978-1981
Author(s)	E.C. Scheuneman
Publisher/Date/Pages	National Research Council of Canada/January 1982
Available from/Price	Division of Building Research National Research Council of Canada Montreal Rd Ottawa, Ontario K1A 0R6
Catalogue & Indexing Numbers	NRCC Building Practice Note No. 27
Key Words	New construction/electrical wiring system/branch circuits
Sector Applicability	Office Residential Restaurants Industrial Retail

Abstract

This report describes an energy use study of four single family detached houses with different insulation levels. Illustrated in the report is an upgraded wall system ("double" wall) in which the electrical wiring is installed between the polyethylene film air barrier and interior finish to eliminate air leakage from electrical penetrations.

Reference No.	6.4.2
Title	Performance of Residential Electrical Wiring System Component Parts
Author(s)	B.C. Research
Publisher/Date/Pages	Canadian Electrical Association/March 1982
Available from/Price	Canadian Electrical Association Montreal, Quebec
Catalogue & Indexing Numbers	CEA Contract No. 000U114
Key Words	Residential electrical wiring/safety/electric devices
Sector Applicability	Office Residential Restaurants Industrial Retail

Abstract

This report studies "the non-safety performance of residential electrical wiring system components by means of a literature review and interviews and discussions with householders, residential electrical contractors, electrical inspectors and other sectors". The performance of some components was deemed unacceptable and included some receptacles, incandescent light fixtures and nylon-sheathed wiring. Evidence of poor quality control was found ranging from untapped holes in switches and receptacles to defective insulation in household wiring. The report "recommends reliability performance standards not on a cost/benefit (dollar savings) basis but rather on level of annoyance encountered, possible safety benefits, and cost in the event of an electrical fire".

Reference No.	6.4.3
Title	Electricity Distribution Within the Future Residence
Author(s)	J.E. Breeze
Publisher/Date/Pages	Canadian Electrical Association/November 1981
Available from/Price	Canadian Electrical Association Montreal, Quebec
Catalogue & Indexing Numbers	CEA Contract No. 000U116
Key Words	Residential electric wiring/new construction/fuse circuit breaker panel/air infiltration
Sector Applicability	Office Residential Restaurants Industrial Retail

Abstract

This study is divided into three phases:

(1) an assessment of the present wiring system identifying desirable features for a future system,

(2) a consideration of current and future residential energy use including alternative energy sources and energy storage systems,

(3) conceptual solutions for a future residential wiring system to meet the functional requirements of (1) and the energy demands of (2).

Comments

The study suggests a lack of compatibility of the present electrical wiring system with new house construction methods. Reference is made to inappropriate wire size for increased thermal insulation thicknesses and the need for better water vapour proofing for outlet and switch boxes.

Reference No.	6.4.4
Title	Residential Non-metallic Electrical Outlet Boxes Literature Review
Author(s)	S.J. Oda
Publisher/Date/Pages	Ontario Hydro Research Division/March 1980
Available from/Price	Ontario Hydro Research 800 Kipling Ave Toronto, Ontario M8Z 5S4

Refer to 6.1.5.1

Reference No.	6.4.5
Title	The National Program Plan for Building Thermal Envelope Systems and Insulating Materials.
Author(s)	P.R. Achenbach
Publisher/Date/Pages	U.S. Department of Energy/January, 1979
Available from/Price	National Technical Information Service Springfield, VA 22161

Refer to 6.2.1.3

Reference No.	6.4.6
Title	Handbook on Insulating Homes for Energy Conservation
Author(s)	Canadian General Standards Board
Publisher/Date/Pages	Canadian General Standards Board/1980
Available from/Price	Canadian General Standards Board Hull, Quebec K1A 0S5 $28.00

Refer to 6.2.4.3

Computer Data Base Descriptions*

Name	Description
Compendex	The Computerized Engineering Index data base covers international engineering literature from over 3,000 publications, including all fields and disciplines of engineering. Prepared by Engineering Information, Inc.
Energy Net	Contains up-to-date, directory-type information on over 3000 organizations and 8000 people in energy-related fields. In addition to organization information, each record contains the names, addresses, and phone numbers of key energy contacts, and a description of the organization's goals where appropriate. This file expands upon EIC's printed Energy Directory. Prepared by Environment Information Center, Inc.
Inspec	Worldwide coverage of physics, electrical engineering, computer science, control engineering, meteorology, astrophysics, hydrology, glaciology, and oceans. Corresponds to Physics Abstracts, Electrical and Electronic Abstracts, and Computer and Control Abstracts. BRS has 1972 to 1976 offline, and 1977 to present on-

* Information extracted from "Directory of Online Information Resources" Ninth Edition. Mar 1982. CSG Press Inc. Kensington, Md.

	line. DIALOG has two files: 1969 to 1976, and 1977 to present. SDC has two files: 1969 to 1976, and 1977 to present. Prepared by Institution of Electrical Engineers.
Magazine Index	Coverage of some 370 popular American magazines. Provides information on general interest topics, including current affairs, consumer product evaluation, sports and recreation, business, environment, and science and technology. Includes all magazines covered by Reader's Guide. Prepared by Information Access Corporation.
National Newspaper Index	Covers business and current events news from New York Times, Christian Science Monitor, and Wall Street Journal.
NTIS	Cross-disciplinary file of citations to US Government-sponsored research and technical reports. Includes analyses prepared by Federal agencies, their contractors or grantees, and nonclassified DOD reports. See DEMNTIS for training file. BRS has two online files: NTIS (1975 to present) and NT74 (1970 to 1974). Prepared by National Technical Information Service.
Safety Science Abstracts	International coverage of general safety, industrial and occupational safety, transportation safety, aviation and aerospace safety, environmental and ecological safety, and medical safety. Citations are gathered from book

reviews, financial news, government affairs, new product news, and patents.

Prepared by Cambridge Scientific Abstracts, Inc.

List of Organizations and Contacts

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Canada Wire and Cable Co Toronto, Ontario	Mr. J. Henderson
Can Am Air Leakage Co Toronto, Ontario	Mr. A. Woods
Canadian Standard Association Rexdale, Ontario	Mr. K. Kameoka Mr. R. White
Department of Consumer and Corporate Affairs Ottawa, Ontario	Mr. R. Viau
Dow Chemical Canada Sarnia, Ontario	Mr. D. Hames
Fiberglass Canada - Sarnia, Ontario - Toronto, Ontario	 Mr. G. Dalton Mr. G. Caunce
Manville Canada	Mr. K. Kinnard Mr. R. Story
Marshall, Macklin, Monaghan Ltd Toronto, Ontario	Mr. H. VanCoorten
National Research Council of Canada - Division of Building Research Ottawa, Ontario	Dr. M. Bomberg Mr. A. Blaga Mr. C. Shirtliffe Mr. K. Solvason Dr. K. Sumi
- Prairie Regional Station Saskatoon, Saskatchewan	Mr. H.W. Orr

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Ontario Hydro	Mr. I. Beare Mr. G. Davidson Mr. R. Hicks Mr. W. Jones
Ontario Ministry of Municipal Affairs and Housing Toronto, Ontario	Mr. A. Zdanowicz
Ontario Research Foundation Mississauga, Ontario	Dr. C. Gibbons
Pacific Gas and Electric Co Oakland, Ca	Mr. P. Murray
Stevens Institute of Technology Hoboken, NJ	Dr. Wyles
US Consumer Product Safety Commission	Mr. E. Krawiec
US National Bureau of Standards Gaithersburg, MD	
- Center for Building Technology	Mr. T. Faison Dr. L. Galowin
- Center for Fire Research	Mr. D. Evans

APPENDIX C

Residential Electrical Wiring Types

CSA Designation	Approximate Certification Date	Temp Rating °C	Prescribed Construction		
			Insulation	Sheath	Jacketing/Coating
Knob and Tube	1938	60	Rubber	Cotton	Wax, asphalt
NMD-1	1951	60	Rubber/PVC	Cotton	Wax, asphalt
2	1951	60	Rubber	-	Neoprene
3	1951	60	PVC	Cotton	Wax, asphalt
4	1951	60	Rubber	-	PVC
5	1951	60	Rubber	Cotton	Wax, asphalt
NMD-1	1957	60	Rubber	Cotton/Rayon	Rubber
3	1957	60	PVC	Paper/Fibre	PVC/Neoprene
NMW-9	1957	60	PVC (Moisture Resistant)	Paper/Fibre	PVC
NMW-10	1957	60	PVC (Moisture Resistant)	None	PVC
NMD-1	1965-05			Deleted	
3	1965	60	PVC	Paper/Fibre	PVC/braid
6	1965	75	PVC	Paper/Fibre	PVC/braid
NMD-7	1966-02	90	PVC	Paper/Fibre	PVC/braid
NMD-3	1970	-	-	Deleted	-
NMW-9	1976	-	-	Deleted	-
NMD-7	1977	90	PVC	Nylon	PVC
NMD-7	1980	90	Crosslinked Polyethylene	Paper/Fibre	PVC

POOR

QUALITY

ORIGINAL